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MECHANICAL ENGINEERING

· JULY 1948 ·

Orville Wright . . . . . *W. F. Durand* 581

Engineering an Orderly Lowering of Prices . . *C. W. S. Parsons* 586

Lubrication Phenomena . . . . . *John Boyd* 589

Technique of Experimenting in the Factory . . . *L. A. Seder* 593

Nonmetallic Bearings:

I—Some Characteristics of Soft Rubber as a Material for Water-Lubricated Bearings . . . . *A. Bednar* 599

II—Some General Information About Lignum-Vitae Bearings . . . . . *H. V. Townsley* 600

III—Properties and Applications of Laminated Phenolic Bearings . . . . *L. E. Caldwell and John Boyd* 601

IV—Reduction of Wear in Rubber Stern Bearings by Flow-Controlled Continuous-Film Method . . *R. D. Smeallie* 607

The Importance of Cores in Die-Casting Design . . *C. R. Maxon* 609

Engineers and Politics . . . . . *R. V. Wright* 614

Departments

Briefing the Record, 616

ASME Technical Digest, 628

ASME News, 41

Keep Informed, *Adv. Pg.* 41

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MECHANICAL ENGINEERING

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Contents for July, 1948

ORVILLE WRIGHT . . . . . *W. F. Durand* 581
ENGINEERING AN ORDERLY LOWERING OF PRICES . . . . . *C. W. S. Parsons* 586
LUBRICATION PHENOMENA . . . . . *John Boyd* 589
TECHNIQUE OF EXPERIMENTING IN THE FACTORY . . . . . *L. A. Seder* 593
NONMETALLIC BEARINGS:
I—SOME CHARACTERISTICS OF SOFT RUBBER AS A MATERIAL FOR WATER-LUBRICATED BEARINGS . . . . . *A. Bednar* 599
II—SOME GENERAL INFORMATION ABOUT LIGNUM-VITAE BEARINGS . *H. V. Townsley* 600
III—PROPERTIES AND APPLICATIONS OF LAMINATED PHENOLIC BEARINGS . . . . . *L. E. Caldwell and John Boyd* 601
IV—REDUCTION OF WEAR IN RUBBER STERN BEARINGS BY FLOW-CONTROLLED CONTINUOUS-FILM METHOD . . . . . *R. D. Smeallie* 607
THE IMPORTANCE OF CORES IN DIE-CASTING DESIGN . . . . . *C. R. Maxon* 609
ENGINEERS AND POLITICS . . . . . *R. V. Wright* 614

EDITORIALS 579
BRIEFING THE RECORD 616
ASME TECHNICAL DIGEST 628
COMMENTS ON PAPERS 637
REVIEWS OF BOOKS 638
ASME BOILER CODE 640
ASME NEWS 641
CONTENTS OF ASME TRANSACTIONS . 656

INDEX TO ADVERTISING PAGES . . . 96

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Charles Phelps Cushing

"Gateway to the West"

(Design for a stainless-steel memorial arch, 590 ft high, 630 ft span, which won first prize in the Jefferson National Expansion Memorial competition, proposed for erection on Mississippi River levee at St. Louis, Mo.)

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MECHANICAL ENGINEERING

JULY
1948

GEORGE A. STETSON, *Editor*

Precision Investment Casting

DURING the late war the need for producing millions of small turbine blades urged manufacturers of gas turbines and similar apparatus to turn to the ancient "lost-wax" casting process which has long been used in the dental and jewelry industries. The materials used, high-melting-point alloys which are able to withstand excessive temperatures, corrosion, and abrasion, are difficult to machine and to forge, and in many cases such methods of manufacture are practically impossible. Intricate shape, small size, and the necessity to hold the product to close dimensional tolerances added to the difficulties of economical mass production of such parts by customary methods. The lost-wax process, however, overcame most of these difficulties and hence provided a means of manufacture which was badly needed in the emergency. So successful were the results that several commercial foundries of this new type were set up.

Our readers have already been given a brief summary of the process as carried out by the Haynes Stellite Company at Kokomo, Ind., in our May and July issues of 1946. Engineers who attended the 1948 ASME Semi-Annual Meeting at Milwaukee had an opportunity to see what progress the Allis-Chalmers Manufacturing Company has made with this modern casting technique; and early in June a group of editors were privileged to inspect the foundry of the International Nickel Company at Bayonne, N. J., where production of small intricate parts by the lost-wax method is now in full swing. Although the term lost-wax process has a time-honored significance, the modern manufacturing technique has been given what may be the more appropriate name of precision investment casting.

Because precision investment casting is relatively new as a manufacturing process the number of foundries is relatively small and many designers are still unfamiliar with it and the possibilities it holds for them. It will not drive from the market other special processes, for example, powder metallurgy, die casting, and forging. It has its own limitations, just as these other manufacturing processes have theirs, but it has important advantages with which the designer must become familiar. At present, for example, the precision investment casting process is limited to parts weighing under five pounds, although heavier castings, up to 20 pounds, have been made. The labor cost is relatively high. Hence economical production depends on large manufacturing lots, or upon making a part which, because of resistance to high temperature, corrosion, or abrasion inherent in the materials that can be cast, has a much longer life, or upon avoidance of machining or other operations difficult or impossible to perform because of the stubborn properties of the metals used or the intricacy of the design to be reproduced.

Precision is a relative term at best and in this process its practical limit is a tolerance of five thousandths of an inch per inch. But when the layman considers the numerous steps of the process—the transfer from master pattern to metal mold, from metal mold to wax pattern, from wax pattern to refractory mold with its drying and baking requirements, and the final casting of the part and its cooling and removal from the mold, in all of which allowance must be made for the shrinkage from master pattern to final product—he is amazed that delicate and intricate shapes do not warp or that close tolerances can be held.

In many of the applications so far made of precision investment casting the characteristics of the alloy are of prime importance and the product must not only be inspected for dimensional accuracy but for soundness and homogeneity of the metal. As the metal is melted in electric furnaces, each charge being sufficient to cast a single mold, composition of the material can be controlled by the old principle that what goes into the pot comes out in the mold. In forging or machining from bar stock it is always possible to get a test specimen of material from as many bars as seem to be indicated, with reasonable assurance that every piece made from a given bar will have identical characteristics. To approach this condition with precision investment casting it is possible to combine with the pattern certain test specimens which are integral with it when the casting is poured. To test soundness, where this is necessary as in the manufacture of airplane-engine or gas-turbine parts, x-ray and similar techniques are employed. Visual inspection of finished parts and checking for dimensional tolerances and warping are carried on in accordance with customary procedures.

Briefly, the process of precision investment casting is carried out as follows: A master pattern, usually of steel highly finished or chrome-plated, is provided by the purchaser or made from his designs. This is placed in a metal mold box made like a foundry flask in two parts. Plaster of Paris is used to set the master pattern in one half of this flask with a carefully made parting line. The other portion of the flask is then assembled over the one containing the master pattern and is filled with a low-melting-point alloy under pressure. The plaster is then removed and the other half of the metal mold is similarly cast. Provision is made for metal cores, some of which are extremely complicated. The completed metal mold

with its cores is then filled with a wax under pressure. A wax replica of the original master pattern results and the mold is used over and over again. Wax pouring sprues with necessary gating are also formed by the same process and are attached to the wax patterns. After the sprues are attached and possibly several wax patterns assembled to be cast together in a single melt, the wax is dipped in water glass and then in fine silica sand. This provides the smooth hard refractory surface of the investment mold in which the casting is to be made. A paper-lined metal flask is then placed on a metal plate and held to it by a fast-hardening wax. The wax pattern is placed in this flask which is then filled with a wet sand mixture. The filled flask is set on a vibrating table to compact the wet investment sand around the pattern. These flasks are then dried, the metal plate (on the pouring end of the pattern) is removed, and the hardened sand mixture above the flask, confined by an extension of the paper lining, is cut off. The flasks are then charged into a heating oven where the wax melts and runs out. This wax is recovered for further use and hence, in spite of the original name of the process, the wax is not lost. Passing through another oven the mold is brought up to pouring temperature.

In the meantime a tilting electric furnace has been carefully charged with a sufficient amount of the proper alloy to cast a single mold. When the metal is ready for pouring a flask is taken from the oven and placed on top of the electric furnace and clamped there, so that when the furnace is turned upside down and air pressure is applied the molten metal flows into the mold with sufficient pressure to fill all parts of it. Gravity casting is also resorted to for some of the larger castings. The mold cools and the casting is knocked out of its investment and is blasted to remove any remaining sand. Pouring sprues are cut off, the several castings are cut from one another if more than one is cast in a single mold, the remaining protuberances are removed by grinding, and the product is ready for whatever polishing and buffing is necessary and for x-ray and other inspections.

One has to see the variety, complexity, and perfection of surface detail of the product in order to visualize the possibilities of the precision investment casting process. The designer must realize that the materials he has at his command for use in this process are limited only by what can be melted in the electric furnace and that the composition of alloys, whether standard or special, is determined by what is charged, following careful weighing, into the furnace. Provided present limitations of size and weight are not exceeded, he can produce in these materials thousands of identical parts of any product for which he can provide a single master pattern. Hard metal dies and molds, with their high cost and inevitable wear, are avoided. The cost of the material of which the product is made is usually so small a percentage of the total cost that he can afford to use metals resistant to abrasion, high temperature, wear, and corrosion, if any of these properties are important to him, although these metals may be difficult or impossible to forge or machine and hence would normally have to be ruled out. Even if the part he wishes to produce can be made, say, of brass and easily machined, the tougher alloys that this casting process accommodates may be cheaper in the long run because of their greatly increased life in service. The unique field of precision investment casting is in the mass manufacture of small intricate parts of alloys that cannot be forged or machined, and as that field is growing in importance, designers should study the process and its possibilities.

Supersonic Speed

ABOUT 90 years ago the distinguished first editor of the *Atlantic Monthly*, Oliver Wendell Holmes, an enthusiastic oarsman, wrote of sculling, "This, in sober earnest, is the nearest approach to flying that man has ever made or perhaps ever will make." Twenty-five years later he was to amend this statement after seeing an exhibition of bicycles from Coventry, England, and to observe, "There seems to be nothing left to perfect in the way of human locomotion but aerial swimming, which some fancy to be a conquest of the future." One of those who shared this expectation was Robert Henry Thurston who, in 1881, commenting on the dirigible balloon, wrote in an ASME address, "Our only hope lies in the direction of flying machines, lifted by their own power, not buoyed up by gas," a scheme that "cannot hastily be condemned." In that year Orville Wright was ten years old and engaged, as Dr. Durand relates in his article on the great inventor printed elsewhere in this issue, in building and flying kites. Another twenty-two years were to elapse before Orville Wright, at Kitty Hawk on Dec. 17, 1903, was to make "the first flight in a man-made machine, carrying a man, leaving the ground under its own power, and returning under control to the ground from whence it had started." Yet only four newspapers considered that event worthy of a story.

On June 10, 1948, Secretary W. Stuart Symington revealed that the Bell XS-1 rocket-powered airplane "has flown much faster than the speed of sound many times" at the Muroc Air Force base. That story made the front pages. The XS-1 was piloted by Capt. Charles E. Yeager who thus becomes officially the first man to pierce in level flight what is known as the sonic barrier. In the forty-odd years that have elapsed between the two historic flights, Wright's and Yeager's, man's air speed has increased about twenty-five-fold.

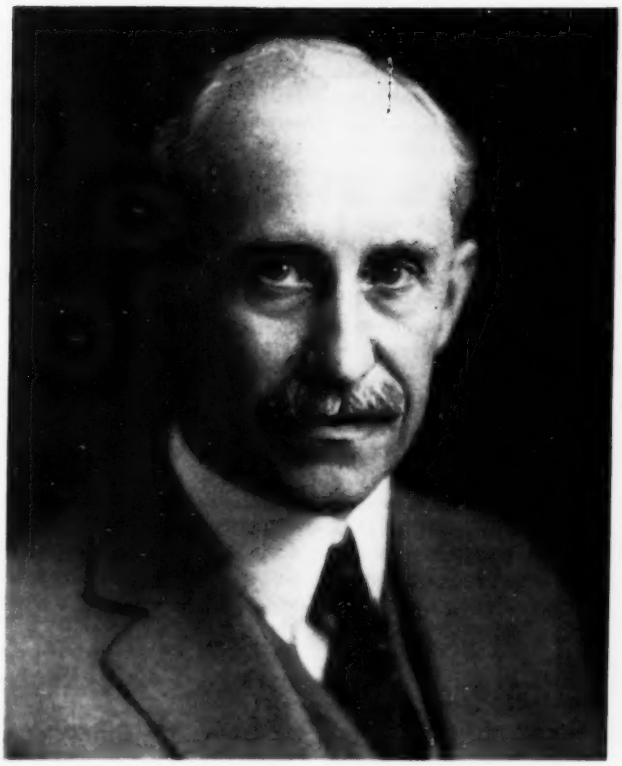
In our issue of October, 1947, we presented two articles on high-speed flight which may bear rereading in the light of the accomplishments at Muroc. One of these, "Developments in High-Speed Aircraft," by E. H. Heinemann, chief engineer, Douglas Aircraft Company, Inc., describes the Douglas D-558 *Skystreak* which made an official record of 650.6 mph on Aug. 25, 1947; and the other, "Research Aircraft," by Col. P. B. Klein, Army Air Forces, describes the XS-1 and the way in which it is launched from its mother airplane.

In contrast to the doubts at the turn of the century that man could ever fly, Colonel Klein concludes his article by stating "we feel reasonably safe in saying that, in so far as we know, there is no limit as to how fast a man-carrying aircraft can be made to fly."

ORVILLE WRIGHT

By W. F. DURAND

STANFORD UNIVERSITY, CALIF. PAST-PRESIDENT AND HONORARY MEMBER ASME



ORVILLE WRIGHT, HONORARY MEMBER ASME

THE boy is father to the man. Never, perhaps, has this old saying been better exemplified than in the life of Orville Wright. Born on August 19, 1871, in Dayton, Ohio, the son of Rev. Milton and Susan Catherine (Koerner) Wright, he began to show in early years the characteristics of mechanical genius and initiative which later, working with his brother, four years older, led to the successful demonstration of aerial flight in a man-made structure.

Placed in kindergarten shortly after reaching five years of age, he began the systematic evasion of the school for association with another boy for play with an old sewing machine belonging to this boy's mother. Orville watched the clock and returned home at the hour he normally would from the school. This went on merrily until his mother, seeing his teacher one day, said that she hoped Orville was doing well. The teacher replied that she had not seen Orville since the first day when his mother brought him, and supposed that she had decided not to send him to the school. What transpired when the actual facts became known is not a matter of record.

Orville was early inculcated with the lesson that if he desired spending money he must earn it, and this he did in a great variety of ways. Wiping dishes, making minor household repairs, and odd jobs of all sorts brought in the small sums which were expended chiefly for tools and mechanical toys.

In June, 1878, when Orville was seven years old, the Wright family removed from Dayton, Ohio, to Cedar Rapids, Iowa, because of the advancement of his father who was made a Bishop of the United Brethren Church. Here, soon after their arrival, the father, returning from a trip on church business, showed to his boys, Wilbur and Orville, a small toy helicopter with propeller driven by a twisted rubber band, the invention of the Frenchman, Alphonse Penaud. This toy when released, flew to the ceiling where it fluttered for a few seconds before falling to the floor. This wonderful toy made a deep and lasting impression on the boys and may be taken as the starting point of their great life interest.

Prepared for the Biographical Memoir Series of the National Academy of Sciences, Washington, D. C., and used with their permission.

Between the ages of young boyhood and early manhood, aside from progression through grammar and high school, Orville Wright occupied his time with a wide variety of enterprises and projects. Among these, the following may be noted: The organization of an army of a dozen schoolboys with himself as general. The life of the army was brief due to the intervention of the school janitor. In June, 1881, the family removed from Cedar Rapids to Richmond, Indiana, where Orville took up the business of building and flying kites. This soon developed into a phase of building them for sale, by which means he obtained his spending money for a time. Next came an ambitious project, the building of a foot-power full-size lathe, in which he was assisted by his brother, Wilbur. Next, with Wilbur and other boys, he organized two circuses which were carried out with parade and success, admission, one cent.

At the age of eleven Orville became interested in wood engraving and this led to the making of a printing press to make prints from his blocks. About this time the family moved again, this time back to Dayton, Ohio, where he renewed his relations with his old chum of kindergarten days, Ed Stines. Young Stines had a small printing press—not much more than a toy—and from this start there developed a long-continued activity in the printing business, through the acquirement of a small but effective press by way of trade for a boat they had made. This activity passed on into the printing and issue of a small newspaper called the *Midget*, together with advertising material for various clients.

By way of diversion from the printing business, Orville and his chum learned the telegraph code and with small toy senders practiced sending messages to each other, which they would later verify by shouted voice. Also, at about this time Orville and Wilbur undertook the somewhat extensive job of adding a front porch to the house and of making some changes in the internal arrangement of the rooms, all of which was highly appreciated by the rest of the family.

Orville's interest in printing led him to take employment during two summer vacations with a printing establishment in Dayton. This was followed by the project of building a full-size press, in which he was assisted by Wilbur. This was

followed by the printing and issue of a small newspaper, the *West Side News*, which ran for a year as a weekly and was then converted into a five-column daily, called the *Evening News*. This ran for a time and was then abandoned for a new interest, bicycles. Orville had owned, in Richmond, a bicycle of the first high-wheel type. Now they found themselves in a position to buy machines of the new chain-drive pattern, and Orville soon became interested in track racing. This was followed by a decision to go into the bicycle business, selling, repair, and manufacture. Two successive moves into larger quarters followed with expanding business. Along with bicycles as the leading line, Orville found odd moments in which to interest himself in a new form of calculating machine, and also in a new and improved form of typewriter.

INTERESTS TURN TO FLIGHT

Starting with the toy helicopter, Orville and Wilbur continued always sensitive to anything in the public press regarding attempts at human flight. In 1895 they were much impressed with accounts of Lilienthal's gliding experiments in Germany and, after his tragic death, their interest became still keener. This led to an appeal to the Smithsonian Institution in Washington for literature references on human flight. In reply, several references were given and when these were obtained, they furnished material for many days' absorbing reading and study. Further reading and study led them to the conclusion that progress toward the solution of the problem of human flight must lie through gliding experiments. Lilienthal became their hero, and they became thoroughly absorbed in this new and enticing problem. This led, in 1899, to the building and flying of a large biplane kite fitted for warping of the wings by means of four cords leading to the ground. This experiment was for the purpose of testing the idea of warped-wing lateral control—a control feature of the first plane to demonstrate, a few years later, the possibility of human flight. The Wright brothers were now fully committed to a serious study of the problem of human flight, first by way of gliding.

Diligent reading of all available literature on the subject was followed by the construction of their first glider in the late summer and early fall of 1900. This was first to be tested by flight as a kite. Inquiry and correspondence indicated the sand dunes of the North Carolina coast as the most suitable location for such tests, and the glider was shipped there and tested during the late fall, both as a kite, and with Wilbur or Orville carried by the glider. These tests, while encouraging, showed, in various respects, marked departures from the results they had been led to expect from such information and data as they had been able to find in their reading.

These tests of 1900 were followed by the construction and tests of a second larger glider in the late summer and early fall of 1901. This second glider was of the same general type and form as the first, with such changes in details as their experience with number one appeared to suggest. These second tests, while still encouraging, showed many departures from what was anticipated from their available information, and presented several new problems relating to the lift and control of cambered surfaces as affected by the travel of the center of pressure on such surfaces under varying angles of attack.

In order to gain firsthand information, Orville constructed a small and somewhat crude wind tunnel in which he made direct measurements of some of these puzzling questions. These results were so interesting and provocative, that the two brothers, in the fall of 1901, made a much larger and more effective form of wind tunnel in which, during the fall, some two hundred forms and proportions of airfoils were tested, and a large amount of useful information obtained. To put these new data to test, a third glider was built and tested in the early fall of 1902 in more than a thousand flights. These flights were very successful and resulted in setting a number of records for gliding flights.

Following this, back to Dayton in the fall of 1902, they set to work on plans for a power flight. The first problem here was the engine. Failing to find a firm willing to undertake the building of an engine with the power estimated as needed and within the limits of weight available, they hired a mechanic and built the engine themselves, of 12 to 16 horsepower and, with accessories, weighing 170 pounds. The design of the propellers was a second problem which gave them much study and some trouble, all of which was successfully met, and propellers, two in number turning in opposite directions in order to balance gyroscopic effects, gave good results later in actual flight.

Finally, in late September of 1903, they had everything in readiness and made their start for Kitty Hawk, N. C.

THE FIRST POWER FLIGHT AT KITTY HAWK

The time required for assembling the plane, installing the motor, and for preliminary tests, together with spells of bad weather, carried the time along to December 17, before an actual power flight was made—the first flight in a man-made machine, carrying a man, leaving the ground under its own power, and returning under control to the ground from whence it had started.

With Orville Wright at the controls, the plane, on a level track, took off after a run of about 40 feet and remained in the air 12 seconds with a run equivalent to 540 feet in still air. This was followed by a second flight with Wilbur at the controls, substantially a repetition of the first flight in time and distance. Two further flights were made, the last of which, with Wilbur at the controls, lasted 59 seconds with a run over the ground of 852 feet.

Thus after more than three years' time, given very largely to this enterprise, the possibility of human flight was fully demonstrated.

Then followed two years of intensive further development in a 68-acre flying field about eight miles from Dayton.

First in January of 1904, they began the building of a new plane along the general lines of the Kitty Hawk plane, but heavier, stronger, and with many changes in detail resulting from the Kitty Hawk experience. A new engine was also built and installed. In this plane they made hundreds of flights in their field, working at improvements and changes as indicated by experience. By the fall of 1905 they had made two record flights, one of $20^{3}/_{4}$ miles in thirty-five minutes, seventeen seconds, and one of $24^{1}/_{5}$ miles in thirty-eight minutes, three seconds.

PUBLIC REACTION ONE OF DISBELIEF

Regarding publicity of the first flight on December 17, 1903, the brothers had desired that it emanate from Dayton, and a telegram was sent to their father briefly announcing the results. Through a leakage at Norfolk, a reporter of the Norfolk *Virginian Pilot* got a tip and published a sensational account of which the details were drawn from his own imagination. Following this, the reaction of the public at large and especially of the press seems now absolutely incomprehensible. The Norfolk *Virginian Pilot* reporter sent a brief outline of the story to twenty-one newspapers in the United States with an offer of the full story. Only five were sufficiently interested to reply, and of these only three printed the story. From this time on for the next three years the Wright brothers, with all of their continued experimental work adjacent to Dayton, were practically ignored by the press. Editors simply refused to believe the story. Finally, however, nearly three years after the event, the *Scientific American* in its issue of December 15, 1906, printed an editorial

announcement in which the editor accepted the truth of the flight and spoke of it as an "epoch-making invention of the first successful aeroplane flying machine."

Curiously enough, the first serious attempt to give this great news to the public was by way of a small periodical *Gleanings in Bee Culture*, owned and edited by a man named Root. In several issues of his journal, Root reported on the Kitty Hawk flight and on the various flights of 1904 and 1905, but these notices gained little or no recognition from the press at large. There was widespread disbelief in the possibility of human flight and a feeling of incredulity in such widely scattering references to the Wrights and their work as, infrequently, appeared in the press.

WAR DEPARTMENT LACKS INTEREST

If the attitude of the public at large and of the press is now hard to understand, that of government officials, especially those of the War Department is still more so. The Wright brothers from the first were very desirous of giving to the government the full benefit of their discoveries and of their invention of a practicable flying machine. To this end they had desired to offer to our government a world monopoly on all their patents and to impart to the proper officials all of their information regarding the design and construction of the plane.

Already England had approached the Wrights, showing a definite interest in what they had accomplished and had asked them to submit a proposal to the War Office. They were in no hurry to do this, however, desiring to give their own government a first chance. They wrote, therefore, on January 18, 1905, to their member of Congress, outlining what they had accomplished and asking him to learn whether such performance was of interest to the government. The letter was forwarded to the Secretary of War who, in turn, passed it on to the Board of Ordnance and Fortification.

The reply was largely a form letter in no way responsive to the Wright communication, and assumed that they had not yet brought their invention to a practicable condition.

There was some further correspondence with the British War Office, but it finally appeared that the British were more interested in obtaining information as to what had been accomplished, than in acquiring a plane for themselves. Octave Chanute, a pioneer himself in aeronautic research, and a close friend of the Wrights, urged them to make another approach to the U. S. Government. Accordingly, they drew up and sent a letter to the Secretary of War offering to build and deliver to the War Department an airplane capable of carrying an operator with a supply of fuel sufficient for a flight of 100 miles and with a minimum speed of 30 miles per hour for a distance of twenty-five miles; the plane not to be accepted until after the successful performance of these requirements.

This letter received a reply as little responsive to the proposal as did their first letter. The reply assumed that they were applicants for a grant of money for the development of the plane, and appeared to assume that the airplane under proposal was still in an undeveloped and experimental stage. This was followed by further correspondence which accomplished practically nothing in developing any basis of dealing with the Wrights, or in evoking any real interest in the Board of Ordnance and Fortification in the subject.

Finally, in the spring of 1906, Godfrey Cabot of Boston, learning of this situation, wrote to his relative, Senator Henry Cabot Lodge, who forwarded the letter to the Secretary of War, together with a letter of his own. This all went again to the Board of Ordnance and Fortification. It was then proposed to send a representative of the Board to Dayton to observe the results of the work of the Wrights, but no such representative was sent. After further desultory correspondence, the Board wrote on May 22, 1907, requesting the Wrights to make a formal proposal. This was forwarded on May 31. This was followed by correspondence regarding the price and other details of the proposal, all of which resulted in nothing until some time later.

FRENCH COPY WRIGHT DEVELOPMENTS

In the meantime the French were becoming deeply interested in the Wrights and in reports of what they had accomplished. Copies were made of the Wright plane and experimental work was carried on. With increase in the tempo of this interest, the Wrights became involved in a lively correspondence with France answering inquiries for information. Then followed visits in Dayton by representatives of French interests of one sort or another. Along with this keen interest in France, there was no lack of incredulity, especially among members of the Aero Club of France. With reports of visitors returning from Dayton and with the gradual accumulation of evidence, however, the performance of the Wrights became generally accepted, and out of this grew the granting by the Wrights of an option to the French War Ministry for a limited time, for the purchase of a plane of stated performance and at an agreed price of $200,000.

Just at this time, there was trouble brewing with Germany over Morocco, and it is believed that the interest of the Ministry was due to the desire to have an airplane available for scouting missions. In the end this resulted in nothing. The Moroccan situation became eased, it was believed the crisis was past, and the Ministry failed to exercise its option.

In 1906 the Wrights were engaged in developing a new airplane engine. Their work was, about this time, brought to the attention of the Charles R. Flint Company of New York who were interested in new developments of importance, and who had connections in Europe. This developed rapidly into a proposal from Mr. Flint to act as the business representative of the Wrights, especially with reference to contacts in Europe. In May of 1907 a telegram came from Flint to the Wrights, urging that one of them should start for Europe at once. Wilbur was followed by Orville who arrived in Paris in August. This was followed by visits to London and Berlin. Nothing of importance came of these visits and business discussions, and Wilbur returned to the United States in November of 1907, followed a little later by Orville.

FIRST UNITED STATES CONTRACT

Returning from France, the Wrights found a distinctly more favorable attitude in the U. S. Board of Ordnance and Fortification, and after some conference and discussion, a basis for a contract was agreed upon.

The specifications called for a machine to be tested in the presence of Army officers, capable of carrying for one hour a passenger besides the pilot, with an average speed not less than 40 miles per hour in a ten-mile test, and carrying enough fuel for a flight of 125 miles.

The War Department was strongly condemned in the press for asking such extremes of performance, it being asserted in the press that no such performances had as yet been demonstrated, or were indeed believed possible.

The Wright bid was accepted February 8, 1908, and construction was promptly begun. On March 3 of the same year a contract was signed with a wealthy Frenchman for the organization of a syndicate to buy the rights to manufacture, sell, or license the use of the Wright airplane in France. With these two governments showing an active interest in the Wright airplane, the period of public disbelief in the possibility of human flight began to shift over into one of qualified belief and later into a definite acceptance of the reality of what the Wrights had accomplished.

Test flights were to be made in France and the plane for the U. S. War Department was to be tested at Fort Myer across the

Potomac River from Washington. It was finally decided that Wilbur should go to France and Orville remain to carry out the tests at Fort Myer. These tests extended over a period of two weeks, some eight or ten in number, definitely establishing the fulfillment of the specifications and with continued increase of record performance. On the last flight, September 17, 1908, something went wrong with the controls and the machine crashed, killing Lieut. Thomas Selfridge, Jr., who, at his own request, was a passenger. Orville Wright himself was seriously injured, with three hipbone fractures and a dislocation of one of them.

Toward the last of December, 1908, Orville Wright, recuperating from his injuries at Fort Myer, went with his sister Katherine to France to join Wilbur. The latter had been most successful in his demonstration flights, and great enthusiasm was in evidence throughout France. Demonstration flights continued at Pau in the South of France, attracting great interest, among others, of King Edward VII of England, and of King Alfonso of Spain. After further demonstration flights in Rome, the Wrights returned to Paris and then went to London whence they returned home to Dayton.

Next came the final test flights at Fort Myer in 1909 which were successfully carried out, chiefly by Orville, resulting in substantial advances beyond specification requirements and in a corresponding bonus beyond the purchase price.

Immediately after completing these U. S. Army tests, Orville Wright set out for Berlin in accordance with an understanding reached with German authorities on the previous visit to Europe. This visit was for the purpose of training German pilots and giving exhibition flights. The latter, given in the Tempelhof grounds and at Potsdam, were successful in the highest degree and awoke unbounded enthusiasm in the spectators. In October of 1909, he took up the German Crown Prince for a flight, the first airplane flight with royalty as a passenger. His last flight in Germany was a twenty-five-minute run at which Kaiser Wilhelm was an interested and enthusiastic spectator. He then sailed with his sister for New York, arriving on November 4, and thence home to Dayton.

WRIGHT COMPANY ORGANIZED

Companies for the manufacture of Wright's airplanes had been organized in France and Germany, and a plane had been sold in Italy before any serious attempt was made by American industry to undertake such manufacture. Finally, on November 22, 1909, nearly six years after the Kitty Hawk flight, a company was organized for this purpose, with many impressive names in business circles on the list of stockholders. The Wrights realized that the time was not yet ripe for manufacture on any large scale, and a decision was reached to undertake the development of a more widespread interest in flying through flight exhibitions. For a time this constituted the chief activity of the company, following which a gradual shift over into manufacture developed.

Aside from occasional exhibition flights, Orville Wright, during this period, devoted most of his time to the supervision of engineering at the factory in Dayton, while Wilbur was occupied in looking after patent litigation with which the Wrights were grievously plagued for some years about this period—finally, however, winning out in the most important of these suits.

Tragedy was just ahead. On May 30, 1912, Wilbur Wright died, and Orville succeeded him as president of the Wright Company. In 1913 he made a trip to Europe on business relating to a patent suit in Germany and at the same time sanctioned the organization of a Wright Company in England.

During 1914 Orville Wright bought up all the stock of the Wright Company except that held by his friend, Robert J. Collier. This move was for the purpose of uniting the stock of the company practically under one name and then selling out, thus retiring himself from active association with the business. This was accomplished in 1915, and his holding was taken over by a group of eastern capitalists.

SMITHSONIAN CONTROVERSY

Over a period of some thirty years from 1910, much of Orville Wright's attention was taken up with an unfortunate controversy with the Smithsonian Institution, finally settled to Mr. Wright's satisfaction by a statement by Dr. G. C. Abbott, Executive Officer of the Institution. In the years about 1910 there was correspondence between Mr. Wright and the Smithsonian Institution regarding a flying machine or a model of one for deposit in the National Museum, along with the model of the Langley plane which fell into the Potomac River in a trial flight nine days before the successful flight of the Wright plane at Kitty Hawk in 1903. When first exhibited in the National Museum in 1918, the Langley machine bore the simple title, "The Original Full Size Langley Flying Machine, 1903." For this simple label, others were substituted later containing the claim that Langley's machine "was the first man-carrying aeroplane in the history of the world capable of sustained free flight."

There was never any controversy as to who first "accomplished" sustained free flight. That was everywhere conceded to the Wrights, but the claim that the Langley machine was "capable" of such flight was challenged by Mr. Wright in defense of his own and of his brother's pioneer achievements. Nothing came of the early correspondence regarding the furnishing, by the Wrights, of a model or a full-sized plane for exhibit in the National Museum but finally, in 1914, resulting from a proposal by Glenn Curtis of Hammondsport, N. Y., it was decided to turn over the original Langley machine to Mr. Curtis for an attempt to prove that this structure was capable of sustained free flight.

Numerous changes were made in the machine, some of them of definite importance to the test, and with these changes, a few flights were made over Lake Keuka, N. Y., none exceeding five seconds in duration. Following this the Smithsonian announced in its Annual Report for 1914, that the Langley machine "has demonstrated that with its original structure and power, it is capable of flying with a pilot and several hundred pounds of useful load...." This claim was again challenged by Mr. Wright and a long and very unfortunate controversy resulted. Finally, in 1928, Orville Wright, in reply to a request from the Science Museum, South Kensington, London, sent the original Kitty Hawk flight plane to that Institution for exhibit.

Dr. G. C. Abbott became Executive Officer of the Smithsonian Institution in 1928, and took up the task of carrying on negotiations with Mr. Wright regarding the matters at issue between him and the Institution. Finally it settled down to the proposal that Dr. Abbott should prepare a statement for review by Mr. Wright, covering the salient points at issue. Several draughts were made of such a statement and it was not until 1942 that one was finally drawn up acceptable to Mr. Wright. In this statement Dr. Abbott stated, "It is to be regretted that the Institution published statements repeatedly to the effect that these experiments of 1914 (at Hammondsport, N. Y.) demonstrated that Langley's plane of 1903, without essential modification, was the first heavier than air machine capable of maintaining sustained human flight."

In addition to a brief history of the controversy with Mr. Wright, the Abbott statement contained a long and detailed list of the changes made in the Langley machine before undergoing the Hammondsport tests. With the acceptance of this

statement by Mr. Wright as satisfactory to him, the way would appear to be open for the return of the Kitty Hawk machine to its native land, and to an honored place in our National Museum.

WRIGHTS RECEIVE MANY MEDALS AND OTHER HONORS

The Wrights were the recipients of many awards and medals. The list for Orville Wright includes the following: B.S. Earlham College, Indiana, 1909; LLD, 1931; Dr. Tech. Sci., Royal Technical College, Munich, 1909; LLD, Oberlin, 1910; Harvard University, 1930; Huntington (Indiana) College, 1935; Sc.D., Trinity, 1915;, Cincinnati, 1917; Ohio State University, 1930; M.A., Yale, 1919; Dr. Eng'g, University of Michigan, 1921; Dr. Sci., Otterbein College, Westville, Ohio, 1947; Dr. Engrg, University of Dayton, 1943; Award of Collier Trophy, 1913; Gold Medal, Aero Club of France, 1908; Aero Club of United Kingdom, 1908; Academy of Sports of France, 1908; Aero Society of Great Britain, 1908; Congress of U. S., 1909; State of Ohio, 1909; City of Dayton, 1909; Aero Club of America, 1909; French Academy of Sciences, 1909; Cross of Chevalier of Legion of Honor, French, 1909; Cross of Officer of Legion of Honor, 1924; Langley Medal, Smithsonian Institution, 1910; Elliott Cresson Medal, The Franklin Institute, 1914; Albert Medal, Royal Society Arts, 1917; John Fritz Medal, 1920; bronze medal International Peace Society; John Scott Medal, 1925; Washington Award, 1927; Distinguished Flying Cross Award, 1929; Daniel Guggenheim Medal, 1930; Franklin Medal, 1933; Hon. Member Aero Club of Sarthe, France; Aero Society Great Britain; Aero Club of U. S.; Oesterreichischen Flugtechnischen Vereines, Vienna; Verein Flugtechniker, Berlin; The American Society of Mechanical Engineers; Aero Society of America; Institution of Mechanical Engineers, London; National Academy of Sciences; Hon. Aircraft Pilot Certificate, No. 1, issued by Civil Aeronautics Authority, 1940.

In 1915, by act of Congress, the National Advisory Committee for Aeronautics was organized, and Orville Wright was appointed by President Wilson, one of the civilian members. This post Mr. Wright held until his death, with quite regular attendance twice a year (annual and semiannual meetings) in Washington. He thus served as a member of this Committee for some thirty-three years.

Due to the accident at Fort Myer when Lieut. Selfridge was killed, Mr. Wright received severe back and hip injuries requiring some replacements by metal. This condition caused severe pain when traveling by railroad due to the jar and tremor of the car, and his keen devotion to duty to the Advisory Committee for Aeronautics is shown by his willingness to subject himself, at least twice a year, to the train ride from Dayton to Washington for attendance on these meetings.

After his retirement from active business pursuits, Orville Wright lived quietly at his home in Dayton. For occupation he spent much time with the records of the extended research work carried on both before and following the Kitty Hawk flight; with work in his laboratory on new ideas of interest to him; and with reading. He was an active and interested reader—fiction, biography, scientific journals, with occasional turns to an encyclopedia. He often read late at night, and most of his late evenings were spent in this way. His chief public obligation was attendance on meetings of the National Advisory Committee for Aeronautics. He was also greatly interested in the Dayton Art Institute and in the Engineers' Club of Dayton. Among the projects worked on in his laboratory may be noted an automatic record changer for phonograph; a cipher machine during World War II, for the purpose of speeding up the transmission of cipher messages; and an improved form of typewriter. In connection with the subject of inventions, mention may here be made of the system of airplane control by wing-warping mechanically connected with rudder control, which embodies the aerodynamic equivalents of the system employed at the present time. Mention may also be made of the fact that while wind tunnels had been constructed in Europe, the wind tunnel of the Wrights was the first in the United States.

1928 PILGRIMAGE TO KITTY HAWK

An event of supreme interest to Orville Wright occurred in December, 1928. This was a pilgrimage, organized by the National Aeronautic Association, to Kitty Hawk, to the site of the first flight in 1903, twenty-five years earlier. This pilgrimage was participated in by members of the Aeronautic Association, members of the National Advisory Committee for Aeronautics, members of Congress, Officers of the Army and Navy, and other high Government officials, with of course Mr. Wright at the head of the list—some 200 in number.

The Congress of the United States had authorized the erection of a national monument on Kill Devil Hills by an act signed by the President on March 2, 1927, and the National Aeronautic Association had authorized the erection of a memorial on the spot from which the first Kill Devil flight took place. The cornerstone of the national monument was laid on December 17, 1928, at 2 p.m., by the Hon. Dwight F. Davis, Secretary of War, with appropriate addresses, and the memorial of the National Aeronautic Association was unveiled on the same day at 3 p.m. with an address by Mr. John F. Victory, Secretary of the National Advisory Committee for Aeronautics. The national monument is a shaft of Monterey granite some fifty feet in height, while the memorial is a ten-ton granite boulder with a bronze tablet suitably inscribed.

Orville Wright had the reputation of never having made a public address. On two occasions, however, he made a close approach. When the two brothers returned to New York from Europe in 1909, Wilbur made a speech at a Lawyers' Club in New York and when he had finished, Orville was introduced and called upon for a few words. He replied, in effect, that he agreed with everything that Wilbur had said, and sat down. Another occasion was when the National Advisory Committee for Aeronautics held a meeting in Orville Wright's home in Dayton on December 17, 1936. He had carefully counted the number of members and arranged the chairs in an oval form, but, by oversight, without a chair for himself. As befits a good host he stood for a time until a chair was brought. In the meantime, the regular chairman of the committee being absent, Orville Wright was nominated to preside as chairman of the meeting; whereupon he, standing, undertook to address a seated audience, arguing why he should not be elected to this office. The members noted that he was actually making a speech, which caused him to terminate his remarks abruptly, whereupon he was duly elected temporary chairman.

AWARD OF MERIT

In April of 1946, the President signed the certificate of the Award of Merit to Orville Wright for distinguished service with the National Advisory Committee for Aeronautics during the great war. Due to delays in the War Department, plans for the actual award were delayed until January of 1948, and it was planned that he would come to Washington on January 15 for that purpose, but the condition of his health would not permit and gradually growing weaker, he died on January 30, without personally having received the award.

The name of Orville Wright will always stand as representing a man of fine personal qualities, modest yet firm in holding to what he considered right and justice. He was a great and original thinker, and, with his brother, the first to solve the problem of human flight in a man-made machine, with all that this epoch-making invention has developed into in our own day.

ENGINEERING *an Orderly* LOWERING *of* PRICES

By C. W. S. PARSONS

CONSULTING ENGINEER, LOS ANGELES, CALIF.

ONE does not have to be an engineer to realize what has happened to the price of groceries, but what to do about it is something else. It is possible that the engineer may be able to contribute to a solution of the problems involved.

Fundamentally, it is desirable that the lowering of prices be accomplished in an orderly fashion. An important point in any plan of approach to the problem would be to establish, as a reasonably attainable objective, the principle that fair dividends should be paid regularly, even in times when business falters. Today, dividends are good, generally, but many companies only pay dividends in peak years. Therefore, any sound policy, which opens up the possibility of continuing dividends, offers some incentive for executives, currently rushed with profitable business, to give the matter some attention.

Another factor demanding equal consideration is that of stabilizing wages at a high level during a period of receding prices. That condition alone spells slowly expanding markets; to achieve it, steps of a clearly defined nature must be taken, for which there is ample precedent in the experience of some of our leading industrial units.

What is actually happening today is that in many quarters prices are running ahead of the pocketbooks of thousands of people (particularly the so-called "white-collar" group, including engineers). That should supply reason enough, while business is at a high level, to concentrate on the problem of how to stimulate a healthy relation between prices, profits, employment, purchasing power, people, and prosperity.

When prices run ahead of pocketbooks, there is usually shrinkage of purchasing power, and sales fall off. This is true in general, and also in connection with specific products or services, in which case there is what amounts to competition on the basis of relative values. When sales fall off, the effect is much the same as what happens when physical productive capacity is built ahead of demand. The total capacity of the particular branch of industry cannot in the circumstances be operated without creating a vigorous competitive struggle to divide up the market.

Those who were actively in touch with business affairs during the period between the two world wars have a vivid recollection of high prices, shrinking markets, cutthroat competition overproduction, the drying up of profits, considerable want in the midst of plenty, lack of demand because of lack of money, and a host of other economic ills.

The palliatives and cures offered at the time were not particularly satisfactory. There was talk about ethics in buying and selling, and the discouragement of price manipulation. Price-fixing was legally ruled out but practically was necessary. There were codes, which offered just enough enticement to lead thousands of businessmen to consider seriously selling the precious freedom to manage their own enterprises in exchange for some sort of guarantee of profit instead of loss.

Yet the answer to the problem was known then, as it is known now. There were executives then who put their fingers on the key log in the jam. Their companies came through, not wholly unscarred, but sound. In numerous instances, and in spite of adverse circumstances, their dividend records were good. When a herd stampedes, it creates a certain amount of destruction. It costs money to ride out an economic storm. Even when operations are maintained at a reasonable level, there are disturbing factors. However, before considering how the companies which act as economic stabilizers function, even in the face of upset conditions, it is pertinent to the solution of the problem to determine what happens to the ones that contribute to the upset, and how they go about it.

HOW THE STAMPEDE STARTS

When prices run ahead of pocketbooks and sales fall off there is a conventional or traditional reaction on the part of many if not most industrial and business managers. In order to spread overhead to cover as large a volume of sales as possible to keep away from the break-even point, and to avoid depleted returns, they launch a drive for full-capacity output, offering goods at close-margin prices, thus figuring on earning the necessary over-all profit on volume business.

But, in the circumstances, the profit rarely materializes. Competition retaliates against the drive by cutting prices to "buy back" the part of the business it considers its own. This is the standard pattern of cutthroat competition. In normal times, in very few businesses or industries is the over-all demand likely to average two thirds of capacity. This is what stamps the drive for full-capacity operation shortsighted and largely ineffective. The unending struggle to divide up limited markets is what creates the recurring cycles of boom and bust.

Whenever competitive price-cutting starts, profits begin to disappear. When or before losses occur, it is considered necessary to curtail expenses. People are removed from the pay roll. Supply sources may be pressured to shave prices, and orders are cut down. There is a cumulative decrease in purchasing power which follows a kind of chain reaction through the channels of supply and trade. If the effect reaches far enough and is strong enough there may be marked economic stringency and even a "bust."

There seems to be something of a blind emotional drive behind this way of doing business. It is almost as if people had a feeling of fatalistic impotence regarding whatever falls within the realm of what might be called the "economic weather." That is, it would seem so except that there are companies, most of them in the blue-chip corporation dividend-paying class which, when there is a shrinkage of purchasing power and sales fall off, act according to the principle that dividends come from profits, not from volume sales.

Just as there has always been a lot of futile talk about the atmospheric weather without anything being done about it, until engineers decided there should be a way to apply some of the techniques learned in other activities, so perhaps the time has come for engineers to study further the pertinent principles and the experiences of others in order to discover

a way to influence the economic weather and, in particular, local situations to control it.

FUNDAMENTALS OF SUCCESSFUL BUSINESS

To show that there is material upon which to base such a study it might be pertinent to call the roll of the country's blue-chip corporations particularly the ones which have good earnings records to determine how they qualify as economic stabilizers, to find out their operating policies, and to analyze what they accomplish with regard to the following:

1 Regular payment of dividends year in and year out.
2 Continual improvement in the values of products.
3 Progressive improvement in operating methods.
4 Gradual but definite lowering of production costs except in periods like the present when inflationary shocks boosting costs have to be overcome by patient determined effort.
5 Corresponding reduction in prices again, except in very unusual times like the present.
6 Steady expansion of markets.
7 Generally high average wages.
8 Constantly increasing number of workers except when a general slump in purchasing power reduces sales.

If the economic pattern which involves cutthroat price competition and the boom-and-bust routine makes for an inevitable and constantly recurring struggle to divide up limited markets, the pattern we are seeking to clarify is the opposite. It calls for competition in productivity and makes for stabilized activity designed to minimize the economic peaks and valleys created by the upheavals caused by traditional business expedients. It consists in exerting unceasing efforts toward creating and supplying markets containing plenty of customers by offering better and better goods and services at lower and lower prices.

COMPETITION IN PRODUCTIVITY

In order to engineer successfully a situation based upon the principle of competition in productivity it is necessary to have a clear understanding of what constitutes sound pricing policy. There are numerous terms in the economic equation all of which must be provided for satisfactorily if a real solution is to be found. Scrutiny of the following will show how important is pricing policy in getting the correct answer:

1 The people who furnish the capital with which an enterprise is financed are just as much entitled to be paid regular dividends for the use of their money as anyone else is entitled to be paid for doing work as an employee of the organization. It has even been proposed that top management bear the risks of operation and only receive payment after workers and stockholders are paid. Thus, good management would be rewarded and bad management penalized. However, for the purpose of this analysis, it is sufficient to recognize that stockholders must receive reasonable dividends regularly, just as banks must be paid interest on loans. As a practical matter, it must be emphasized that without providing for dividends regularly, the directors of few corporations would feel free to authorize continually the regular expenditure of considerable sums of money for an equally essential purpose.

2 This equally essential purpose, and, in many respects, a prime factor in any regime of competition in productivity, consists in finding ways and means of producing better and better goods and services at lower and lower cost, as has already been stated. To do this, it is necessary to spend money on a continuing program of research and development.

3 Of necessity, this program of research and development is designed to appraise and find ways of improving organization management itself, and the operations of engineering, sales, finance and accounting, procurement, production, and personnel. The objective is to uncover and make use of the best in techniques and processes.

4 The method of organizing such research and development, whether as a special function under general management, or as a series of separate assignments the general manager orders carried out by or for department heads, and others, would depend upon the circumstances. The point would be to get the work of research and development done thoroughly and systematically by people who can and will spend the necessary time and thought free of immediate operating demands.

5 In order to obtain the funds to pay for regular dividends and for the cost of a thoroughgoing program of research and development, it is necessary that a normal volume of business be obtained, at prices providing a fair margin of gross profit. How to obtain such profit regularly was carefully investigated by the late W. L. Churchill, a member of this Society. Churchill performed what amounted to a classic in research, during the 1920's, in an effort to determine why so many companies having well-run production facilities only paid dividends in peak years.

6 Churchill[1] found that in order to earn what amounted to the economically sound profit on a normal volume of business a definite expenditure of selling effort is required. This sound profit objective Churchill claimed to be equal to the conversion cost, or in the case of distribution operations, the service cost. Conversion cost equals manufacturing cost, i.e., productive labor, factory overhead, and the part of administrative cost attributable to production. It includes no element of selling expense or cost of purchased material.

7 As previously indicated, profit or earning power is related to selling effort. Through advertising and sales it is necessary to acquaint a sufficient number of people with the values offered. The cost of this selling effort, Churchill determined to be as follows:

(*a*) On sales, manufacturer to wholesaler or to another manufacturer, selling cost is one half of conversion cost.
(*b*) On sales, manufacturer to retailer, the selling cost is equal to the conversion cost.
(*c*) On sales, manufacturer to ultimate consumer, the selling cost is twice the conversion cost.
(*d*) These criteria govern for normal volume of business, earlier described as output corresponding to ratio of over-all demand to over-all capacity of the business. Ratio of profit to sales effort does not hold when the expenditure for sales is markedly under or over normal.

8 Many of the dividend-earning companies investigated by Churchill knew nothing about his method of constructing prices, but apparently their price "curves" coincided with his in the range corresponding to the operations they were performing. This occurred so often that he pursued the idea systematically, working by a process of elimination, until he became convinced that he had discovered principles which might prove to be fundamental laws. His ideas stand up under careful scrutiny; others who knew him and those who examined his records, agree. Certainly, any program of research and development would be incomplete without there being a careful appraisal of his findings.

9 The following breakdown demonstrates Churchill's

[1] "Pricing for Profit," by W. L. Churchill, The Macmillan Company, New York, N. Y., 1932.

conversion-cost method of pricing for the case of an article sold by the manufacturer to the ultimate consumer.

Productive labor	$ 25[a]
Factory overhead	35
Conversion cost	60
Profit[b]	60
Material, at cost	100
Advertising and sales	120
Factory price to consumer	$340

[a] Assumed amounts.
[b] The cost of research and development is included.

10 Churchill declared that the price to the ultimate consumer should not be higher when distribution is effected through a wholesaler-retailer chain, assuming that the same services are rendered, otherwise distributors become economic burdens. There is reason to believe, in some instances, that distributors do not put in the economically required selling effort to bring in a normal volume of business at full profit.

A FIELD FOR THE ENGINEERING APPROACH

It would seem as if engineers especially would see real value in the approach to commercial and industrial operation so briefly discussed in the foregoing. The kind of pricing policy, specifically contemplating an active program of research and development, opens up almost unlimited opportunities for expanding markets and creating jobs. This can be accomplished through systematic search for and adoption of better techniques and processes, and better ways of organizing and performing the various functions of a business.

From the point of view of a manufacturer, this approach provides means whereby the sales staff can be released from the toils of competitive price manipulation and get busy with the job of "selling the company and all its works;" enthusiastically revealing to buyers the values they are getting at the steadily improving prices, by reason of the continuing and thoroughgoing developments always under way at the factory.

Note, too, that the objective of such a program is to start today to engineer costs to the point where ultimately, even in a tight buyers' market, the company will be in the position of meeting cutthroat price competition at a profit.

According to Churchill the conversion-cost method of building prices helps to eliminate the under- and over-pricing of individual items, with consequent direct improvement in profits, but without necessarily raising the general level of prices of the whole of the company's output.

From the point of view of an industrial organization buying materials or supplies, the absence of this kind of pricing policy behind the program of a vendor could be the signal for caution, and the occasion for pointed suggestions by the purchasing agent as he tries to find out just what he would be getting at the prices quoted.

If, in the business of buying, the seller can be made to explain the content of the values offered, it is not beyond reason to say that a factory's decision to buy could be understood to depend partly upon whether the pricing policy of a vendor proves that he is competing in productivity rather than in price-cutting.

Likewise if the business of selling can be made the means of educating the buyer on the content of the values offered, it is not beyond reason to say that the buyer's decision to purchase could be influenced by his becoming aware of the operating program and the pricing policy of the vendor.

Prices are not just things to accept passively, as for example, the "best of three bids," or some similar basis. The engineer knows he can determine what it costs to produce goods or to supply services. With reasonably sound pricing techniques as guides, he can "fabricate the tools" with which to "sell" the vendor on the reasonable cost to produce and the fair price to charge.

One dictionary definition of engineering is "painstaking management." If painstaking, which means diligent and careful endeavor, can be considered legitimately as being something actuated by intelligent appraisal of facts and fundamental principles, as opposed to hunches, hopes, and emotionally influenced drives, it does look as if the time has come for engineers to sprinkle some dry logic into a few cloudy thoughts and see if they cannot find out how to go about making fair economic weather. One of these days it is going to be needed.

The various principles herein discussed can serve as a starting point for any company which really is determined to find ways and means of getting prices, that is, their prices, going downward in an orderly manner but still serving to pay them fair profits.

Certainly it is reasonable to suppose that an early subject for widespread research and development would be pricing policy and its relation to competitive productivity and profitable operation.

CONCLUSION

In concluding, it should be observed that efforts of enterprises, generally, to free themselves from various forms of government restraint and interference presumably could be made to accomplish more, if the widespread adoption of research and development, designed to improve organization management and the various operating functions, was shown to be creative of better values, lower costs, reduced prices, expanded purchasing power, and broader markets.

It must be realized that only strong and effective leadership would make it possible for the force of public opinion to be marshaled in a move to influence operators in various fields of endeavor to take active cognizance of these principles. It is also true that individual companies can benefit by their adoption, regardless of what their neighbors or competitors do.

Those who do take advantage of these principles will have a stabilizing influence at such time as a contraction in business occurs. The degree of such influence will depend upon their number with relation to the thousands resorting to cutthroat competition.

It is just possible that in the last analysis it will be the engineers who take time by the forelock and individually and collectively generate the imaginative steam that will serve to start prices moving downward, a step at a time, in the orderly manner necessary to the economic well-being of the country.

ONE may well ask: "What is the true function of the Engineering College?" One major purpose of a technical education is, of course, preparation for earning a living but the real function of the engineering college does not lie in mere vocationalism or training for a specific job. Vocational training has no aims beyond itself. True higher education trains the mind, and education for a profession such as engineering can and should be concerned with underlying principles rather than solely with the acquisition of specialized knowledge and techniques. Such an education will turn out not mere technicians but men adaptable to the jobs they find, men equipped with a fine sense of integrity, with an insatiable curiosity, an ability to discern the true from the false, the mediocre from the excellent, and a respect for the orderliness of a universe which finds itself best interpreted in scientific laws and principles. Thus we can logically conclude that the education of the engineer is not merely a matter of method but importantly one of breadth.—T. KEITH GLENNAN.

LUBRICATION PHENOMENA

Use of Transparent Models for Purposes of Demonstration and Study

By JOHN BOYD

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OVERSIMPLIFICATION of a problem often obscures the real nature of the actual phenomena involved. Thus the journal bearing, prior to the time of Reynolds, was considered to be nothing more than a shaft in a hole. As a result, many of its characteristics of operation could not be explained.

Reynold's application of the principles of hydrodynamics for ideal cases, and the extension of the application to practical examples by others have made it possible to correlate theory and experiment. However, the nature of the expressions obtained, and the number of factors involved make it difficult to obtain a clear picture of the interdependence of the different variables without considerable study.

As an aid in demonstrating some of the principles of hydrodynamic lubrication, and as a help in giving added meaning to the analysis, simple transparent models may be used.

One of the advantages of transparent models is that they permit observation of the lubricating film and detection of discontinuities and differences in thickness by variations in film color.

Transparency also permits the path of the lubricant to be traced through the bearing by introducing filaments of dye into the oil film.

A further advantage is that, by providing small holes at different points, the pressure of the film at each of these points will be indicated by the height to which the lubrication rises in the holes.

Until recently, glass was the only transparent material available, but because of fabrication difficulties it was little used. However, the advent of transparent plastics, which can be machined and polished easily, has altered the situation considerably.

This paper describes the construction and operation of simple slider- and journal-bearing models, by means of which it is possible to show the pressure developed in an "oil wedge," the position of the maximum pressure, the effect of speed, viscosity, and so forth.

Another use to which transparent models may be put is the determination of the extent to which the idealized conditions used in analyses are borne out in practice. Most analyses assume the bearing to be supplied with a full fluid film. Practically, this is not always the case, as may readily be seen from a model study. The models are particularly useful in determining the effectiveness of grooves, reliefs, and the like.

Although other discussions of the use of transparent models probably exist, a survey of the literature by the author uncovered only the paper by Barnard,[1] which describes a glass bearing used to study flow patterns.

References to other types of demonstration apparatus are more numerous. Two of the more important ones are the Kingsbury air-lubricated thrust bearing[2] and the McKee lubrication indicator.[3]

FABRICATION OF TRANSPARENT MATERIAL

The models used to date have been made from transparent acrylic resin which is available in rods, tubes, sheets, and blocks in a wide variety of sizes.[4] In block form, the cost is about $1.65 per lb (density, approximately 0.07 lb per cu in.).

The usual rules of machine practice apply to the machining of acrylic resin which has working qualities similar to those of brass. The cutting edges of the tools should have no rake and should be sharp and free from nicks and burrs. Since the resin is a poor heat conductor, and since it is also thermoplastic, softening will occur if it is machined at too high a speed. In cases where machining must be done across surface discontinuities, light cuts and small feeds should be used to prevent chipping at the edge where the tool leaves the work. Machined surfaces should be as smooth as possible to facilitate polishing.

Drills used for metal may also be used for acrylic resin, but better results are obtained if the drills are ground with a very small lead. The drill should be withdrawn frequently to prevent the hole from being clogged by the cuttings. When drilling through a piece of resin, the pressure should be relaxed toward the end of the drilling operation to prevent chipping. Long holes such as the $1/16$-in-diam holes of the present models can be drilled by ordinary drills to which extension pieces have been silver-soldered.

Acrylic resins are usually polished by buffing with a cloth wheel rubbed with tallow and abrasive. This method is rapid but tends to round off the edges. Rounding can be largely eliminated by hand-polishing, using a solution of No. 3 polishing alumina, and a small felt pad.

The models may be cleaned with kerosene or naphtha. Carbon tetrachloride should be avoided because of its effect on the resin.

THE PLAIN SLIDER BEARING

Figs. 1 and 2 show a model of a slider bearing designed to illustrate the principle of the "tapered oil film" or oil wedge. Either of the 3-in. × 5-in. faces may be used as the sliding surface. One of these faces is flat, the other is provided with a tapered groove. Five $1/16$-in-diam holes perpendicular to the sliding faces permit the lubricant to rise to a height, depending upon the pressure within the lubricating film.

It is most effective to demonstrate the operation of the flat sliding surface first. Pushing the block back and forth in the

[1] "Oil Flow in Plain Bearings," by D. P. Barnard, 4th, *Industrial and Engineering Chemistry*, vol. 18, 1926, p. 460.

Contributed by the Machine Design Division and presented at the Semi-Annual Meeting, Milwaukee, Wis., May 30-June 5, 1948, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[2] "Lubrication," by A. E. Norton, McGraw-Hill Book Company, Inc., New York, N. Y., 1942, p. 8.

[3] "Theory of Lubrication," by M. D. Hersey, John Wiley & Sons, Inc., New York, N. Y., 1936, p. 66.

[4] Manufactured under the trade names of "Lucite" (E. I. du Pont de Nemours and Company, Arlington, N. J.), and "Plexiglass" (Rohm and Haas Company, Philadelphia, Pa.). Manuals giving physical properties and fabrication instruction may be obtained from either manufacturer.

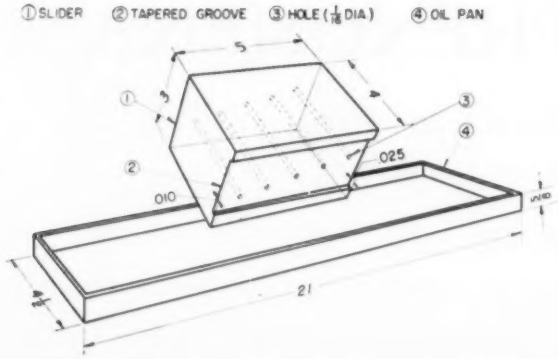

FIG. 1 SLIDER-BEARING DEMONSTRATION APPARATUS

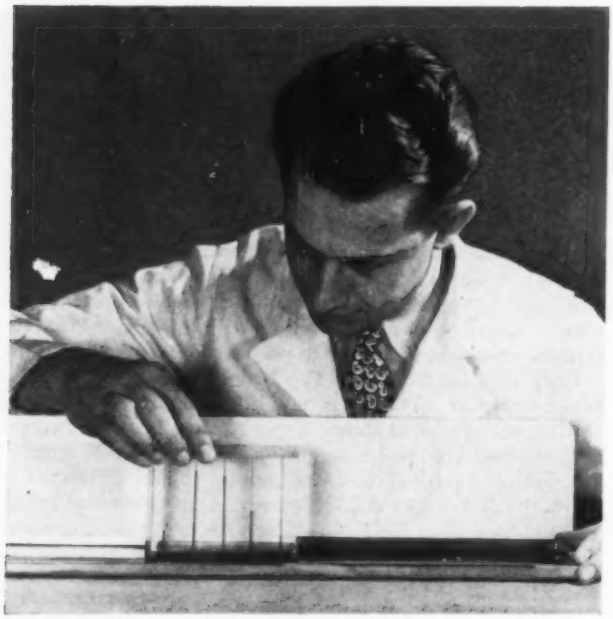

FIG. 2 SLIDER-BEARING MODEL

pan without lubricant will give an idea of the resistance to sliding with dry friction.

A light turbine oil (150 SUV at 100 F, or approximately SAE 10) colored with an oil-soluble dye,[5] such as "Resin Red Z,"[6] may now be poured in the pan around the block. If the block is again pushed back and forth, it will be found that the resistance to sliding will be greater[7] than the resistance encountered for the dry surfaces. The explanation of this apparent paradox is that the front edge of the block permits only a very thin film to be drawn beneath it. Since the force required to shear the film is inversely proportional to the film thickness, the resistance for the thin film is actually quite large. Assuming the film to be a tenth of a mil (1×10^{-4} in.) thick, calculations based upon the viscous properties of the fluid show that the force required to push the lubricated block (at a certain speed) is almost 3 times as great as the force required to push the unlubricated block.[8]

Under normal conditions the motion of the lubricated block is apt to be unsteady. This is due to deviations from perfect flatness of the bottom of the pan. If the experiment were carried out on a scraped surface plate, the motion would also be unsteady but the frequency of the irregularities would be higher. However, if an optical flat were substituted for the surface plate, the motion would be found to be quite smooth.

Assuming that the experiment is carried out in the foregoing manner, no appreciable rise of lubricant in the holes will be observed, indicating that there is no tendency to develop pressure within the film. If, instead of placing the block in the pan and pouring the lubricant around it, the block is put in last, the lubricant will rise immediately in the holes as the block is lowered. Because the clearance beneath the block is small, resistance to the outward flow of the lubricant from the holes will be great, and considerable time will be required for the oil level to reach equilibrium.

If the block is lowered onto the lubricated surface and immediately pushed back and forth, very little resistance to motion will be noted because the film thickness is large. As the lubricant becomes squeezed from beneath the block and the film thickness decreases, the resistance will become greater. Variations in the thickness of the film will be visible throughout the experiment as differences in color.

SLIDER BEARING WITH A TAPERED OIL FILM

By taking the block used previously and turning it over so that the tapered groove is down, the principle of the tapered oil film or oil wedge may be demonstrated.

If the block is now placed in the pan, oil will rise immediately in the holes just as was the case with the plain slider, but, because of the relatively large clearance provided by the tapered groove, the level of the oil in the holes will fall rapidly to the capillary height (about $\frac{1}{4}$ in.).

If the block is now pushed in the direction of the thicker portion of the film so that the flow in the film is converging, it will be found that the oil will rise in the holes to a height proportional to the pressure within the film as shown in Figs. 1 and 2.

From the theory of slider bearings,[9] the pressure developed at any point in a tapered oil film, see Fig. 3, may be computed from the expression

$$p = \frac{\mu v b}{h_2^2} q$$

where

p = pressure, psi
μ = viscosity, reyns (lb sec/in.^{2})
v = velocity of slider, ips
b = length of slider in direction of motion, in.
h_1 = maximum film thickness, in.
h_2 = minimum film thickness, in.
q = factor, depending upon position at which pressure is measured and upon the ratio h_1/h_2

This expression shows that the pressure is zero if the speed v is zero; a relation which may be demonstrated by noting that the pressure falls to the capillary height if the block is stopped.

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[5] Approximately 1cc per pt. Predissolving the dye in a small quantity of carbon tetrachloride will assist in getting a uniform dispersion in the oil.

[6] National Aniline Dye & Chemical Company, Buffalo, N. Y.

[7] This will be true only if the surfaces of the block and pan are flat.

[8] From Newton's expression for viscous flow $\tau = \mu v/y$, where τ is the shearing stress between block and fluid, μ is the coefficient of viscosity, and v/y is the rate of shear (assuming linear velocity distribution).

Assuming velocity, $v = 1$ ips, film thickness, $y = 1 \times 10^{-4}$ in.; $\mu = 15 \times 10^{-6}$ reyns (lb sec/in.^{2}) the force P_1 to shear the film on the 3-in. $\times$ 5-in. face becomes $P_1 = 3 \times 5 \times 15 \times 10^6 \times 1 \times 10^{-4} = 2.25$ lb.

For dry friction, assuming weight of block = 4 lb and coefficient of friction = 0.2

$$P = 0.2 \times 4 = 0.8 \text{ lb}$$

[9] Reference (2), chapt. V.

The direct proportionality between pressure and speed may be shown by pushing the block at different velocities, the higher the velocity, the higher the pressure.[10]

If the motion of the block is reversed so that the flow in the film is diverging, the velocity v, becomes negative, and the pressure tends to become "negative" or to fall below atmospheric. This is demonstrated in the model by the downward flow of air through the holes and into the oil film when the block is moved in the direction of the thinner portion of the film.

The smaller pressure produced by a liquid of lower viscosity may be shown by replacing the turbine oil with kerosene.

The dotted line in Fig. 3 shows the theoretical pressure distribution in the film. It will be seen that the maximum pressure does not occur at the mid-length of the block, but is located approximately $^7/_{10}$ of the distance from point 1 to point 2.

The influence of the thickness and the shape of the film may be illustrated by providing blocks having different grooving. The proportions of the groove employed in the model described were chosen to give optimum conditions ($b_1/b_2 = 2.5$ approx).

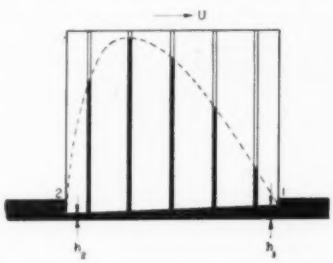

FIG. 3 PRESSURE DISTRIBUTION FOR SLIDER BEARING WITH TAPERED OIL FILM

It is not intended that the foregoing demonstration convey the idea that the machining of a tapered groove on the bottom of a plain slider bearing would produce a practical design. The model should be considered only as a means of illustrating the properties of the tapered oil films which are employed in Kingsbury-type thrust bearings and are inherent in journal bearings.

THE PLAIN JOURNAL BEARING

Figs. 4 and 5 illustrate a journal-bearing demonstration apparatus designed to show certain characteristics of a plain journal bearing. The model consists of an aluminum journal which may be rotated by hand and a 180-deg bearing which rests on the top of the journal in a manner similar to a railway-axle bearing. Attached to the bottom of the bearing are four rods supporting the oil reservoir and a steel counterweight. The reservoir may be adjusted vertically to bring the oil in contact with the undersurface of the journal. The counterweight serves to provide a load for the bearing and as a pendulum weight to produce a restoring moment when friction tends to rotate the bearing. The apparatus is similar in many respects to the equipment used by Beauchamp Tower to obtain the data on which Reynolds developed the hydrodynamic theory of lubrication. Diametrical clearance of the model was 20 mils.

By attaching a pointer to the top of the bearing with a small piece of plasticine and fastening a fixed scale to the journal mount, the coefficient of friction of the bearing on the journal may be indicated directly. The data given in Fig. 4 will give a correct scale for an apparatus built to the dimensions shown.

It is desirable to demonstrate the performance of the bearing

[10] Assuming: $v = 1$ ips
$\mu = 15 \times 10^{-6}$ lb sec/in.^{2}
$b = 5$ in.
$q = 0.25$ for point of maximum pressure
$b_2 = 0.010$ in.
density of oil = 0.0325 lb per cu in.
$p = 0.1875$ psi or $\frac{0.1875}{0.0325} = 5.75$ in. of oil
Thus a sustained speed of 1 ips will cause oil to flow out of the top of the block.

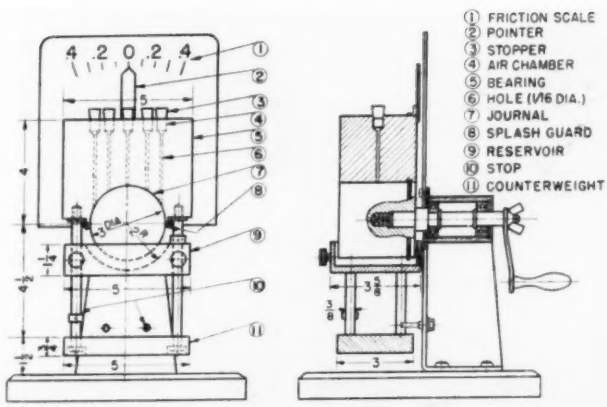

FIG. 4 JOURNAL-BEARING DEMONSTRATION APPARATUS

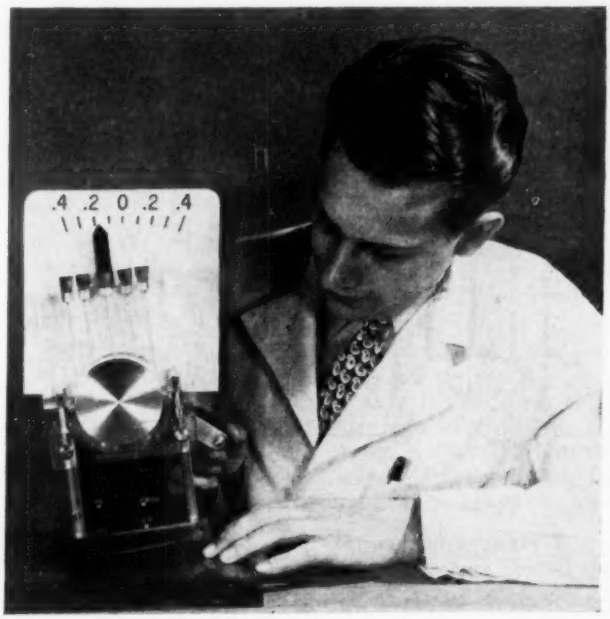

FIG. 5 JOURNAL-BEARING MODEL; WITHOUT LUBRICANT

without lubricant first. If the crank is turned very slowly, it will be found that the pointer will move over to approximately 0.2–0.3, see Fig. 5, before the bearing breaks away. Continued turning will produce an oscillatory motion with the bearing alternately sticking and slipping.

If a lubricant were now introduced and if open holes similar to those used with the slider bearing were employed, convenient operating speeds would produce relatively high film pressures, and oil would overflow from all of the holes. This would prevent noting any differences in pressure throughout the film. By providing a stoppered air chamber at the top of each hole the higher pressures may be handled easily, and the rise[11] of the oil in the holes will be approximately proportional to the film pressure.

When oil is placed in the reservoir and the journal turned over for the first time, the bearing will start under dry-friction conditions since the oil will not be carried to the sliding surfaces until the journal has made about one half a revolution. If the journal is turned very slowly, the film formed will be rather

[11] Without the air chamber, the rise of the oil would be about 25 times greater.

FIG. 6 JOURNAL-BEARING MODEL; WITH LUBRICANT

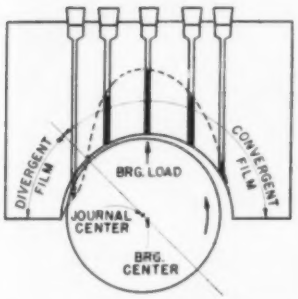

FIG. 7 PRESSURE DISTRIBUTION FOR 180-DEG JOURNAL BEARING

imperfect but the coefficient of friction will be found to decrease. As the speed of rotation is increased, the coefficient will fall almost to zero and the oil will rise in the holes as shown in Figs. 6 and 7.

The similarity between a journal bearing and a slider bearing with a tapered oil film will become apparent from Fig. 7. Because of the differences in radius between the bearing and the journal, a converging film is automatically formed on the "up" side of the bearing, giving rise to a region of positive pressure. On the "down" side of the bearing, the film, being divergent, tends to set up a negative, or subatmospheric pressure.

In starting from rest under conditions of dry friction, the point of contact between the journal and the bearing moves in a direction opposite to the rotation until the friction angle is reached, as shown in Fig. 8, which illustrates a full 360-deg bearing. When starting from rest under lubricated conditions, the journal and bearing will behave initially as though no lubricant were present and the point of contact will, at first, move in the same direction as for dry friction. Since this creates a converging film and hence increased pressure on the up side of the journal, the journal (or bearing, depending upon which is fixed) is displaced laterally so that the point of minimum film thickness moves in the direction of rotation until equilibrium is satisfied. The point of minimum film thickness can be observed on the model as a light-colored region. The shift of this region with journal speed can be seen by careful observation.

The presence of a region of negative pressure can be demonstrated by removing the end stopper so that air may be drawn into the film. Because the region of negative pressure also shifts with journal speed, it will require some experimentation to determine the proper rate of cranking.

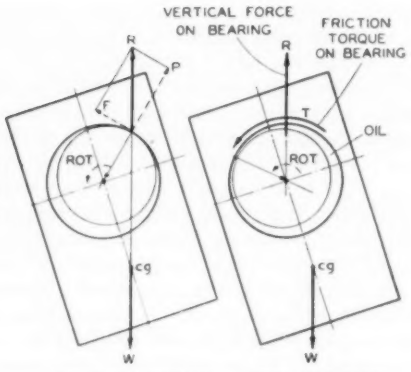

FIG. 8 FORCES ON BEARING BLOCK WITH AND WITHOUT LUBRICANT

WITHOUT LUBRICANT WITH LUBRICANT

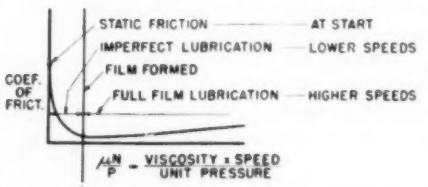
STATIC FRICTION — AT START
IMPERFECT LUBRICATION — LOWER SPEEDS
FILM FORMED
FULL FILM LUBRICATION — HIGHER SPEEDS
COEF. OF FRICT.
μN/P = VISCOSITY × SPEED / UNIT PRESSURE

FIG. 9 CHARACTERISTIC CURVE FOR JOURNAL BEARING

A more striking demonstration of the pressure developed in the film may be made by withdrawing one of the stoppers in the pressure area. Even very slow-speed cranking will cause the oil to rise to the top of the hole and to overflow. It was precisely this same operation which led Beauchamp Tower to make his extensive investigation of the full-film-lubricated journal bearing.

Although the full significance of the so-called "characteristic curve" of coefficient of friction versus $\mu N/p$ (viscosity × speed/unit pressure) cannot be shown by the model, some of its implications may be illustrated by comparing different stages of operation of the model with the curve in Fig. 9. Since the viscosity and the pressure remain constant, only the speed can be varied. Little change in the static or starting friction will be noted whether the journal is started up dry or after shutdown following previous operation with a lubricant. It will not be possible to crank the journal fast enough by hand to illustrate the increase in friction in the full-film-lubricated region.

WICK-LUBRICATED JOURNAL BEARING

By placing a 2-in. × 3-in. × $^3/_4$-in-thick felt pad in the oil reservoir and adjusting the latter so the pad wipes the journal, a felt or wick-lubricated bearing can be simulated.

A noticeable difference in performance between the wick-lubricated bearing and the one described previously is that the wick prevents a thick film from adhering to the shaft. Since the film is not capable of filling the entire clearance space, the bearing load will be carried by a narrow film at the top, and because the load is fixed, the pressure within this region will be noticeably higher than the pressure for the flooded bearing.

APPLICATION TO ACTUAL BEARING PROBLEMS

Transparent models have also been found to be helpful in a number of actual bearing problems. Two interesting cases were a study of groove design for a ring-oiled bearing and an investigation of the proper location for the window in a wick-oiled bearing.

ACKNOWLEDGMENT

The author wishes to thank Mr. R. E. Peterson for his interest and helpful suggestions and Mr. A. Carlson for his skillful workmanship in the construction of the models.

Technique of EXPERIMENTING *in the* FACTORY

By LEONARD A. SEDER

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EVERY factory has its chief trouble-shooter. Sometimes he is the foreman of the job, sometimes the chief inspector, the superintendent, or again the process engineer. Whatever his title, to him falls the job of pressing the right buttons to keep the job humming in a quality sense. Intimate familiarity with the process, ingenuity, detective ability, and horse sense are usually the chief tools in his kit. Frequently, however, the issues are so important that he cannot rely solely on these but must resort to "making an experiment" to let the facts "speak for themselves."

Unfortunately, "facts" thus obtained often speak double-talk. What is a sound conclusion today fails to stand up tomorrow. "Something else must have changed" is the usual disposition of the matter after much head-scratching. What to do with all the "something elses" which constantly get in the way of permitting a straightforward conclusion to an experiment is not always a simple problem.

Lately, two new tools for dealing effectively with "extraneous" influences have been developed. One is the "concept of variation" embodied in the viewpoint of statistical quality control, and the other, its twin sister, is "analysis of variance." Much has been written to explain the former in layman language, but little is available on the latter, possibly because of its inherently mathematical nature.

Statistical methods in the design and analysis of experiments have a great contribution to make to industrial thinking. There is so much to be learned from the cold sheer logic implicit in the design of such experiments that vast improvements in experimental technique can be made from a study of the design factors alone, quite aside from the statistical methods. It is the purpose of this paper, therefore, to show how those who would experiment on industrial processes can profitably take a leaf from the book of the statistician, even though they eschew his statistical methods. In brief, it is an effort to bridge the wide gap between the limitedly practiced ideal experimental technique employing statistical analysis and the much more prevalent hit-or-miss methods.

The inadequacies of present methods are best shown by an examination of some of the typical fallacies of reasoning suffered by those who lack a clear picture of the "concept of variation."

THE GUINEA-PIG FALLACY

The first is what Paul Peach[1] has called the "guinea-pig" fallacy, so-called because it used to occur in medical research as: "Because it is true of guinea pigs, therefore it is true of human beings." It is the fallacy of inducing too general a truth from too limited an amount of data, or of extending an induction from one set of circumstances to an entirely new set of circumstances, under which it is not, *per se*, applicable. This type of fallacious reasoning is so much a part of almost everyone's daily thinking that it requires a conscious effort to overcome it. We judge a new acquaintance by a few chance remarks or even merely by his background. Bitter personal controversies result from too hasty inductions from a few bits of evidence and, even more regrettable, from deliberate omission of evidence which fails to support the induction. People believe generalities which they want to believe. "The wish is father to the thought," as it is said.

A certain shoe manufacturer once tested some samples of a particular plastic material for use in place of upper leather. So poorly did the samples stand up that the executive concluded that all plastics were unsuited for such use. Events since have proved his error. An engineer of the author's acquaintance performed life tests on some pilot-plant samples of a new type of rectifier and published the results, indicating that they were typical of the product's performance. Much to his chagrin, he has never been able to obtain the same results on production samples. An inspection supervisor used to "spot-check" his employees' work daily by sampling from the top tray of the day's skidload as it left his department. Somehow, his results always were at odds with what the assembly department found later. He finally discovered that the routine of picking up the inspectors' work practically guaranteed that the top tray would always be the work of the same operator, who happened to be a very good one.

The cure for the guinea-pig fallacy is to broaden the base of the experiment. Include those variables which, in the normal production cycle, must be "lived with." Include more than one operator, more than one machine, more than one batch of material. In short, make the experiment as truly representative of the production conditions as possible, yet in such a way that the effect of these "extraneous" variables can be evaluated when the experiment is completed. That this can easily be done will be indicated presently.

THE RABBIT'S-FOOT FALLACY

Another type of fallacy commonly found in industrial experimentation is the "rabbit's foot" fallacy. The implication of the rabbit's foot is that a particular piece of good luck befell its owner because he rubbed the poor deceased animal's pedal extremity. It is the fallacy of false cause or of associating an effect with a cause with which it is not, in truth, associated.

Here is one typical example. Trouble in knurling certain brass rod seemed to be associated with a particular vendor's material. At the same time, it was noted that the hardnesses of certain of this vendor's lots were over the specification. Hardness was assumed to be responsible for the poor knurling, and the questionable lots were rejected on the vendor. Shortly thereafter, the knurling operation was shut down for some time, although raw material from the vendor (now within the

[1] "The Use of Statistics in the Design of Experiments," by Paul Peach, *Industrial Quality Control*, November, 1946.

Presented before a Joint Meeting of the Metropolitan Sections of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS and the American Society for Quality Control, New York, N. Y., Feb. 20, 1948.

proper hardness range) continued to pour into the plant and thence to storage.

When the knurling operation was started up again, the trouble was still evident on the material with satisfactory hardness. The answer proved to be in the metallurgical structure, which was discovered after a well-designed experiment covering vendors, hardnesses, and knurling-machine variables showed that the stock was definitely inferior. But the rabbit's foot had done its work and thousands of dollars were sacrificed because the hardness hypothesis was allowed to become a conclusion without being tested.

Perhaps the most common industrial case of this fallacy is the theory that an innovation in material or processing can be evaluated by substituting it for the standard method in production for "a day or two." The experimenter is supposed to be able to conclude that, because the quality of product was better (or worse) that day, it was the result of the innovation.

This is a highly dangerous procedure because of the dynamic nature of the industrial process, which has a whole universe of things which vary with time. Raw materials change, operating personnel changes, gages wear, instruments shift in calibration, alterations (intended and otherwise) are made in instructions, processing methods are improved. One must visualize this galaxy in constant motion, changing ever so slightly from day to day, but presenting as different an appearance 6 months from now as does the night sky in its seasonal movements. Most experiments are intended to discover whether any basic change has been made in this appearance. However, superimposed on this basic appearance are the daily weather conditions—the day-to-day variations—which also alter the appearance of our industrial "sky." The mere fact that a particular constellation is not visible on a particular night is not evidence that its course has been shifted. Instead, a localized weather condition may be responsible. The experimenter must constantly ask himself whether the sky's face has really had plastic surgery or is merely wearing a mask.

Too many times, when innovations are hurriedly tried, localized effects are mistaken for basic ones; and the experimenter is off to another false start. He is guilty of assuming that one thing has caused another thing merely because the second follows the first in point of time.

The surest cure for the rabbit's foot fallacy is to demand that the experiment have an adequate "control." It will be recalled that Pasteur had to resist the impulse to inoculate *all* the anthrax cases with his vaccine so that he would have a controlled group which did not receive the treatment. In the knurling problem cited, a comparison of the knurlability of the material of both hardnesses would have provided the control and would have indicated quickly that hardness was not the answer. If a new method of processing is to be evaluated, it should be run in parallel with the standard on the same lots of product. If a new material is to be tested, it should be compared with the standard material run through the identical setup at the same time. Errors or variations should not be depended upon to "cancel each other" unless a positive effort is made to see that they really do distribute themselves uniformly.

Another way to steer clear of this fallacy is to regard suspiciously any conclusion purporting to show the cause of a particular effect when the argument is based mainly upon the fact that the effect followed the supposed cause in terms of time.

THE SQUEAKY-WHEEL FALLACY

Another type of fallacy frequently encountered in industrial thinking is the "squeaky wheel." It arises from the principle, so commonly practiced, that the "squeaky wheel gets the grease." When this precept dominates shop thinking, it is quite natural that people will also accept the corollary thesis: "If something is wrong with a conclusion, it will 'squeak.'" It says: "If we do not hear any complaints from the foreman, we can assume this new material is O.K." It is the philosophy of negativism.

There are many more would-be experimenters using this philosophy than their superiors would like to believe. They are the purchasing agents who change vendors without confirmation of the department using the material. They are the engineers who change manufacturing instructions without consulting the operating departments involved; they are the inspectors who take liberties with the interpretation of the specifications; they are the operators who pass the bad work along anyway; they are even the superintendents who issue edicts without consulting their subordinates. All depend on being able to conclude that their decisions are right if they do not receive any complaints.

In experimental work, this fallacy arises when decisions are based on the absence of contrary evidence rather than the presence of positive supporting evidence. Often, these decisions are the seemingly unimportant ones relative to the design and method of conducting the experiment. Shall raw material be included as a variable in this test? There is no evidence to show that it is an important variable. Yet, if this fact alone is used as a basis for deciding to omit it, a high risk is taken that the experiment will fail in its primary purpose of showing the causes of variable quality.

The following story has probably been repeated countless times in hundreds of plants. A customer's complaint made it necessary to run some life tests on an electrical gadget with two types of protective finishes. Samples of the product were taken by the laboratory from the production line, given the two types of finishes and exposed to various accelerated weathering and exposure tests. When the tests were completed in 3 weeks and presented to the product engineer, he immediately pointed out that the test was worthless since none of the samples was originally within the specification. In the hurry to start the test, the experimenter had scooped the samples from the line without waiting for routine inspection. He had assumed they were representative samples because no evidence to the contrary existed. He erred in failing to prove their worthiness by a positive check.

The cure for this fallacy is, of course, to avoid decisions which are based on the lack of evidence. An investigation into the facts should be made and positive evidence obtained. Francis Bacon had the answer to this when he wrote: "If a man will begin with certainties, he shall end in doubts; but, if he will be content to begin in doubts, he will end in certainties."

To summarize this criticism of present-day industrial experimenting, three recommendations have been made:

1 The experiment must be broad enough to enable the experimenter to draw as general a conclusion as he hopes to make.

2 The experiment must have a "control."

3 Decisions relative to the experiment should be based upon the presence of positive supporting evidence rather than upon the lack of contrary evidence.

Or, more briefly, *bias* must be consciously minimized in the original plan of the experiment.

THE DEDUCTIVE METHOD

In addition to their tendencies toward fallacies in thought, there are additional reasons from the standpoint of pure logic, why the generally practiced experimental methods fail to solve many of industry's quality problems. These are best

illustrated by an examination of the usual thinking patterns of an experimenter seeking to eliminate a quality disturbance.

One is the straight deductive approach. A screw-machine operator observes that the work from a particular machine has poor surface finish. He has an unsatisfactory result. To explain the result, he must find a cause. He arrives at a tentative cause by deduction, in the manner made famous by Sherlock Holmes. He knows that dull tools produce poor surface finish (major premise). He presumes that this tool is dull (minor premise) and that, therefore, it is producing poor appearing parts (conclusion).

He then removes the tool and sharpens it, basing his action upon the converse premise that sharp tools produce good finish. If this works, it is "proof" that his first deduction was correct. If this fails to correct the fault, the entire mental process is repeated and a new "cause" deduced. Since there are many other possible causes of poor finish, he may have to repeat the process several times before the disturbance is removed.

It is a fundamental characteristic of the deductive method that the experimenter first attempts to explain the result and second to test the explanation. Even the great Holmes often found it necessary to confront the suspect with his deductions to ascertain their validity.

In the type of fairly simple problem just cited, the deductive method can often be used successfully. Most automobile mechanics, radio repairmen, and, in fact, anyone admiringly referred to as a "practical" man will be found to rely almost wholly on this type of attack. Some call it the "trial-and-error" method; others, less charitable, call it "diddling." It is most successful when the applicable major premises are well-established general truths well known to the experimenter and where the time and expense of the "process of elimination" are not significant factors.

It is least successful in a wide area of industrial experimentation where the general laws governing the process are not well understood and where expensive, drawn-out experimenting cannot be afforded.

THE INDUCTIVE METHOD

Another type of thinking pattern is the simple inductive approach. Instead of assuming a general law and deducing a correction, the experimenter seeks to prove the existence of a general law or to show that a known general law is applicable to the problem at hand. The procedure of the experiment becomes first to gather facts, then to explain them, instead of the reverse.

Here is an example: The operator of a plastics molding press observes that some of his pieces are short because of insufficient filling of the mold. To determine whether temperature is responsible, he produces parts at each of several temperatures and carefully observes the results. He may find, for example that the pieces are charred above 300 F, are short below 275 F, but are satisfactory within the 275–300 F range. He has thus learned specifically how the known "general laws" of temperature-plasticity and temperature-oxidation apply to the case at hand. If temperature does not produce the desired effect, he may have to repeat the procedure with injection pressure, material feed rate, nozzle size, and so forth.

In such a fairly simple case, the immediate aim of the inductive method is not the correction of the trouble but the deliberate synthesis or reproduction of the undesired conditions by control of the cause. When it is shown that the effect can be created at will by turning on and off the assumed cause, it is concluded that the "general law" or "cause system" affecting the product has been induced properly. The corrective action needed may or may not be obvious from the simple inductive experiment.

This is the traditional method widely practiced in scientific research. Its fundamental assumption is that everything else can be held constant while the factor under study is varied. Frequently, this condition is actually met in the laboratory (although less so than is generally supposed). Rarely, if ever, does it happen in an industrial process. Thus the purely inductive experimenter is led into an insoluble dilemma. He must do either one of two things:

1 Create a highly artificial environment in which to run the experiment. This leaves him open to committing the guinea-pig fallacy when he attempts to generalize the results.

2 Test the hypothesis in the presence of the production variables. Then he is in danger of the rabbit's foot fallacy since he will never be sure that the result obtained was produced by the consciously varied cause or by the many possible causes.

The purely inductive approach, then, is also limited in use to simple cases. Like the deductive method, its efficiency depends upon how quickly the experimenter can spot the correct hypothesis to examine.

THE DEDUCTIVE-INDUCTIVE METHOD

The most useful method is derived by combining features of both types, as follows:

1 By careful examination of all of the available information (sometimes with the assistance of simple preliminary experiments), the experimenter proceeds to deduce *all* the possible causes for the observed effect. Broadly speaking, these will be found within the categories of men, machine, material, and method.

2 He then designs an inductive experiment in which the samples are so arranged with respect to one another that all of the possible "causes" are contained in a single co-ordinated plan.

3 Upon completion of the experiment, he is able to analyze the results to determine how much, if any, of the observed quality defect was contributed by each of the causes.

This approach has the obvious virtue that, since all of the causes were present and acted on the samples in a known way, the inapplicable causes will be discarded with finality and the applicable ones selected with confidence. In the use of this technique, the entire viewpoint of the experiment may be shifted. The primary objective may no longer merely be to spot and correct the present ailment, but to draw an outline of the main cause systems affecting the quality of the product so that both present and future maladies can be diagnosed.

Those familiar with statistical methods of design and analysis will readily agree that this is the most effective and most efficient method of experimentation. Much of the same general philosophy, however, can be applied without the use of statistics. A brief consideration of the fundamental design factors of the statistically conceived experiment will be necessary to show how this can be accomplished.

DESIGN FACTORS

Having at hand the list of all possible variables conceivably capable of producing the effect under examination, the experimenter's first step is to decide in each case whether the variable will be "standardized," "randomized," or "deliberately varied."

To "standardize" a variable is to limit it to one and only one value or item for all samples of the experiment. The advantage of standardizing a variable is that it keeps down the magnitude of the experiment; it means one less factor to contend

with. By the same token, however, the experiment becomes incapable of shedding any light on the effect of that variable. In the event that it is one of the many unsuspected causes of variation, this may be a serious loss. Moreover, when a variable is standardized, one is prone to commit the guinea-pig fallacy and attempt unjustifiably to extend the results of the experiment to other values of this variable.

To "randomize" a variable is to permit each of the samples of the experiment an equal chance of having any particular value of the randomized variable associated with it. The advantage of randomizing is that it prevents confounding of the experiment. For example, if one lot of material is used on one machine and a second lot on another machine, it will be impossible to state whether the result is characteristic of the material or the machine—the experiment is confounded. One way of randomizing would be to mix thoroughly the two lots of material and select the two machine samples at random from the mixture.

The disadvantage of randomizing is that it pools one more variable into the "experimental error," which is defined for present purposes as the differences between samples treated identically. If, in the foregoing, the two lots of material are, in fact, different, then the variation among pieces of the mixture done on the same machine will be larger than it would be on a single lot of the material.

To "deliberately vary" a variable is to include it as one of earmarked factors of the experiment, using different values on successive samples. The disadvantages of both standardizing and randomizing are simultaneously overcome by so doing, for the experiment will shed light on the effect of the variable, and the experimental error will be kept to a minimum value. In the example cited previously, each material would be run in each machine; thus something would be learned of the effects of both machines and materials, and whatever loss of sensitivity accompanied randomizing would be regained.

VARIABLE	TRADITIONAL	MODERN	STATISTICAL
MACHINE	Standardize	Standardize	VARY
MATERIAL SOURCE	Standardize	*Randomize*	*Randomize*
OPERATOR	Standardize	*Randomize*	VARY
CUTTING SPEED	Standardize	VARY	VARY
FEED	VARY	VARY	VARY

FIG. 1 COMPARISON OF THREE EXPERIMENTAL DESIGNS FOR TYPICAL MACHINING PROBLEM, SHOWING CONTRAST IN METHOD OF HANDLING THE VARIABLES

The disadvantage of deliberate variation would seem to be that inclusion of another variable has made the experiment more complicated, more difficult to perform. In a sense this is true, viz., the initial experiment may be more involved than the initial experiment by traditional methods. However, in this case, the initial experiment is likely to be the final experiment, whereas in the traditional scheme, it is likely to be but the first in a long series of overlapping inconclusive meanderings.

COMPARISON OF TECHNIQUES

It is in the decision as to which of these three treatments shall be given to each variable that the basic distinction is seen between the traditional and statistical experiments. The "modern" technique, using the statistical design principles without the statistics, will also be examined in this respect to illustrate its middle-of-the-road position (see Fig. 1).

In the "traditional" method, all variables except the one under consideration are standardized. As previously explained, this frequently leads to the fallacies already discussed.

In the "modern" method, some variables are standardized, some randomized, and some deliberately varied. Those which are standardized are of two types, i.e., when it is physically impossible to do otherwise or when strong engineering conviction exists that the variable has no effect on the quality characteristic being studied. Two or three or even more variables can be deliberately varied. These will be the ones which are suspected of having an effect and, in general, those about which something can be done in a production sense. Finally, and herein is the core of the method, all other variables are randomized. In general, those to be randomized are those difficult or undesirable to standardize because they are bound up with the production operation. Examples:[2] The position of a particular sample in a multiposition machine; the operator (when there are several doing the same work); the particular machine (when several are run in parallel); or the particular lot of raw or partly processed material.

In the "statistical" method, the scheme is identical with the modern, except that a greater number of variables can be varied simultaneously and thus some of those which were randomized in the modern are deliberately varied in the statistical.

EXAMPLES OF MODERN DESIGN

Examples will now be cited to indicate the applicability of this modern design. Example 1 will show the simplification possible and the greater value realized, as compared with the traditional. Example 2 will show an actual application of the modern method in studying a visual defect condition.

For Example 1, suppose that varying quality results have been experienced with a chemical-etching process on some aluminum parts. It is desired to study the process and correct it by recommending any necessary changes in equipment or procedure. After a preliminary survey, it has been decided that there are four major variables which conceivably could influence the variability of the process. These are as follows:

1 Temperature of the etching tank.
2 The particular tank used (there are four).
3 Variation in lots of raw material.
4 Time of immersion of the parts.

THE TRADITIONAL APPROACH

The strictly traditional inductive approach (see Fig. 2), would probably be as follows:

1 Standardize on one tank and one lot of raw material.
2 Make time-temperature runs at each of about four different temperatures.
3 Repeat each run a second time to see how closely they check.

Assuming four times and four temperatures, this means a total of 32 sets of samples to be tested. (One set of samples

[2] Note that these variables are randomized when they are not the chief variables under study. It is easily conceivable that they might be, in which case they are among the deliberately varied group.

TEMPERATURE

TIME	50°	60°	70°	80°
	10 min.	10 min.	10 min.	10 min.
	20 min.	20 min.	20 min.	20 min.
	30 min.	30 min.	30 min.	30 min.
	40 min.	40 min.	40 min.	40 min.

LOT "A" only.
TANK No. 1 only.

FIG. 2 "TRADITIONAL" EXPERIMENTAL DESIGN FOR ALUMINUM-ETCHING PROCESS
(Time-temperature runs are made for each lot and each tank.)

TEMPERATURE

TIME	50°	60°	70°	80°
10 min.	TANK NO.1	TANK NO.2	TANK NO.3	TANK NO.4
20 min.	" NO.4	" NO.3	" NO.2	" NO.1
30 min.	" NO.3	" NO.4	" NO.1	" NO.2
40 min.	" NO.2	" NO.1	" NO.4	" NO.3

LOT "A, B, C, D," RANDOMIZED BY MIXING.
TANKS ALL RANDOMIZED BY ARRANGEMENT.

FIG. 3 "MODERN" EXPERIMENTAL DESIGN FOR ALUMINUM-ETCHING PROCESS
(Tanks and lots are included in time-temperature runs. Effect of tanks can be evaluated.)

TEMPERATURE

TIME	50°	60°	70°	80°
10 min.	TANK NO.1 LOT A	TANK NO.2 LOT B	TANK NO.3 LOT C	TANK NO.4 LOT D
20 min.	NO.4 B	NO.3 A	NO.2 D	NO.1 C
30 min.	NO.3 D	NO.4 C	NO.1 B	NO.2 A
40 min.	NO.2 C	NO.1 D	NO.4 A	NO.3 B

LOTS ALL RANDOMIZED BY ARRANGEMENT.
TANKS ALL RANDOMIZED BY ARRANGEMENT.

FIG. 4 "STATISTICAL" EXPERIMENTAL DESIGN FOR ALUMINUM-ETCHING PROCESS
(Tanks and lots are included in time-temperature runs and effect of each can be evaluated.)

might be perhaps 5 aluminum pieces.) The operator will undoubtedly get some information on the effect of time and temperature, but will it apply to the next lot of material or to another tank? He does not know and so he may have to repeat the entire procedure with each of three more lots of material in the same tank. Now he will have tested 128 sets of samples. He still needs to know the effect of tanks, so he repeats the experiment again, this time using the three other tanks with one lot of material. This makes 224 tests. He should be getting a fair idea of which variables influence the result if he can keep up with the paper work. (Note that he has not made all the possible combinations, however. If a double run were to be made with each material on each tank, it would require the astounding total of 512 sets of samples.)

THE MODERN APPROACH

The modern technique (see Fig. 3) would be applied as follows:

1 Randomize raw materials. Mix all four lots of material until they are homogeneous and draw out samples at random.

2 Randomize tanks. Use the different tanks in a predetermined order in such a way that the effect of tanks cannot be confounded with any other variable.

3 Under these conditions, make a time-temperature run at each of four temperatures.

This procedure requires 16 sets of samples. The data thus obtained will be realistic. The process may not be as sharply focusing on a particular time and temperature as were the first 32 tests in the previous method, but it will tell the range of time and temperature likely to be satisfactory with the normal amount of material variation and the four pieces of existing equipment.

If, on the other hand, it should turn out that tanks or materials are the real controlling variables and time and temperature make little difference, it will be apparent in that the variability of pieces treated identically (i.e., at the same time and temperature) will be excessive compared with the effect of time and temperature. It will then be necessary to run a second experiment, now standardizing time and temperature, and deliberately varying materials and tanks.

The statistical design (see Fig. 4) is similar to the modern, except that raw material is now included in the purposely varied group instead of being randomized. Tanks are used in the same way as in the modern, but the statistician will be able to analyze separately the effect of tanks. Thus the possible need for a second experiment is virtually eliminated. This method also uses only 16 sets of samples and, when the analysis has been completed, it will be easy to decide which variables need finer control in production or must be studied further, and which variables can be eliminated as having no effect.

A CASE IN POINT

An actual case in which modern design was successfully applied without the need for statistics will now be cited. A factory had experienced difficulty in hot-pressing a resin-coated paper to a metal sheet. The method consisted simply in placing the paper and metal in contact between electrically heated platens and exerting pressure with a jack-screw. After cooling, many of the papers lifted or "blistered." While good adhesion was required, no appreciable flow of the resinous material could be permitted, since the paper was punched with 188 tiny holes which could not be allowed to fill with resin.

Four possible causes were considered as being operative:

1 Excessive temperature variation in the platens.
2 Insufficient resin on some of the paper.
3 Insufficient time allowed for full adhesion.
4 Excessive pressure variation because of the hand method.

Accordingly, an experiment was designed to test variables (1, 2, 3). Better engineering judgment would have included (4), as will be apparent. Pressure was standardized by providing a torque wrench and the other three variables were varied in a manner similar to that shown in the previous example. The results are shown in Fig. 5. The rectangular pieces are the metal plates, with the paper stripped off to reveal the extent of adhesion. Light areas indicate poor adhesion. The numbers under each plate are observations of the number of holes plugged up by resin flow out of the total of 188 per plate (known as the "squeeze-out").

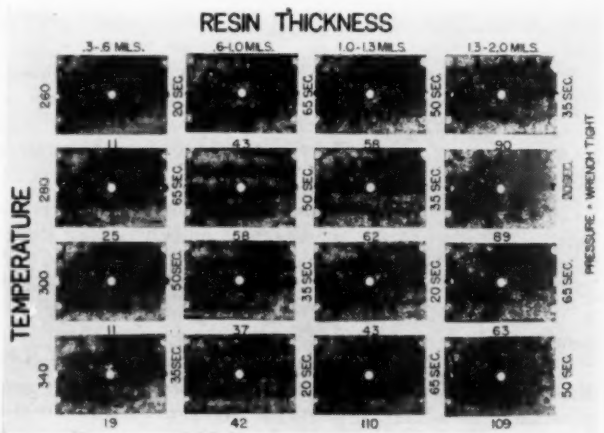

FIG. 5 RESULTS OF FIRST TEST ON ADHESION PROBLEM, SHOWING PLATES WITH PAPER STRIPPED OFF
(Similarity of adhesion patterns suggests pressure distribution as cause.)

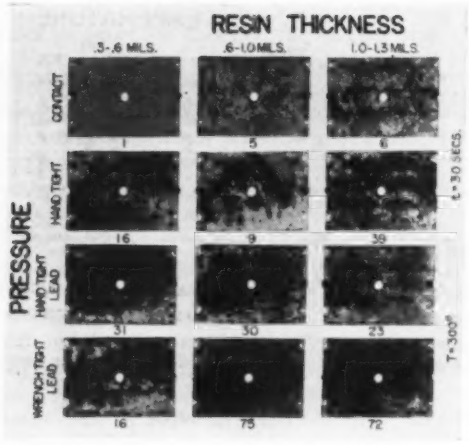

FIG. 6 RESULTS OF SECOND TEST
(Effect of pressure on adhesion patterns is clearly shown.)

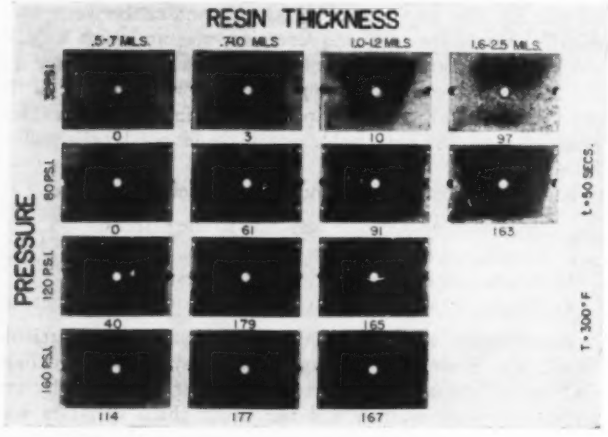

FIG. 7 RESULTS OF THIRD TEST
(Adhesion patterns are much improved and proper operating pressure is determined.)

The following was apparent from these samples:

1 Time and temperature, within the range studied, were without appreciable effect on either adhesion or squeeze-out.

2 Resin thickness affected squeeze-out decidedly, but not the adhesion.

3 Pressure was probably the important factor on adhesion. This inference was drawn from the fact that the pattern was the same in all samples, which could be easily explained if the pressure was not being uniformly distributed over the surface of the platen.

The experimenter was not content with obtaining merely an inference, however, and therefore he quickly set up another experiment to demonstrate the pressure effect and, at the same time, made efforts to smooth out the pressure distribution by placing lead sheets on the platens on some of the samples.

The pressure effect was then clearly demonstrated, as shown in Fig. 6. Those with only hand or contact pressure show practically no adhesion, while the higher pressures show good adhesion. Note that time and temperature could now be standardized, already having been ruled out by the first experiment.

Since pressure was the important effect, it was necessary to design a third experiment in which measured pressures were employed, in order to have precise data for correction. Also, a better method of distributing pressure was found in the use of heat-resisting neoprene sheeting. Fig. 7 shows the results of the third test. Here much improved adhesion is evident, and the results clearly indicate the range of pressure and resin thickness necessary to give the optimum balance between adhesion and squeeze-out; viz., a resin thickness of 0.5 to 0.7 mils and a pressure of 80 psi.

All three of these experiments were completed within 2 days, and the results were immediately put to use as follows:

1 Resin-thickness specification was changed and tolerances reduced. The range had previously been 1.0 to 2.0.

2 An air-pressure cylinder replaced the hand-screw method of obtaining pressure, thus providing finer and measurable control of pressure. Neoprene sheeting was used on the platens.

3 A proposition to purchase a more expensive temperature regulator was turned down, with confidence.

4 The time allowed for the operation was reduced by one third.

The net effect was elimination of the trouble, reduction in cost of the operation, and restoration of the confidence of all concerned on the suitability of the apparatus for the use.

CONCLUSION

This type of experimenting "pays off" in many ways other than the solution of the immediate problem, although that in itself should be enough to justify it. The value of a well-designed experiment cannot be overestimated. It wins the respect of vendors when material problems arise. It wins the confidence of customers when complaints are answered. It is a sure-fire way of resolving responsibilities in the inter-departmental problems where several causes may be operative, and each department seeks to avoid the onus by emphasizing the weaknesses of the other departments. A technique that does all this can and should be afforded in industry today.

THERE are certain essentials in an engineer's education which he must be prepared to assimilate as he grows in stature in his profession. He must prepare himself to assume a wider field of activity, broader social, political, economic and moral responsibilities.

The first of these essentials is the ability to express himself fluently, clearly and logically in good English, both in written and spoken words. . . . . .

I regard a study of history as a second great essential in an engineer's education. A thorough study of history may seem to a student of the sciences as a wholly irrelevant matter. Yet, I venture to say that from a cultural point of view in rounding out a man's perspective and helping him to understand the world in which he lives, the world in which he came from, and the world toward which he is moving, no study could be more effective, particularly if the history he is taught is based on the economic forces which created the tides underlying almost all the great movements in history. . . . . .

A third essential for today's job is a basic grounding in the principles of economics. I think it is appalling that we have allowed our people generally to be exposed to our educational system without grasping a clearer notion of these fundamentals.

As a fourth essential and beyond these studies, to be fully equipped to lead, the engineer must recognize moral and spiritual values in life in order to have a sympathetic understanding of his fellow man. It is here that religion can do its part in making the engineer a full man.—JAMES D. MOONEY.

NONMETALLIC BEARINGS

I—Some Characteristics of Soft Rubber as a Material for Water-Lubricated Bearings

By A. BEDNAR[1]

MANY years ago, an engineer, operating mining equipment in the west, presumably far removed from the sources of supply, was having much difficulty in maintaining bearings in a pump required to handle muddy and sandy water. The sand and grit would cut out the bearings at a rate far exceeding the rate of supply, and so inevitably he eventually ran out of spares.

In desperation, the story goes, he wrapped a section of discarded rubber hose around the shaft in the place of the bearing, and this arrangement, it is said, not only outlasted the original bearing several times, but caused much less wear to the shaft. That, supposedly, was the first application of soft rubber as a water-lubricated bearing.

Another legend describes the inventor as wearing rubbers on a rainy day, slipping on a wet manhole cover, and being jarred into the idea of water-lubricated rubber bearings; a sudden thought apparently, something like the Eureka episode of ancient Greece.

Be that as it may, these accounts indicate some desirable properties of soft rubber for bearings under conditions of water lubrication. Water lubrication, as applied today, generally because of necessity, imposes an abrasive problem of varying degree in almost all cases.

TWENTY YEARS OF SERVICE

Bearings of soft rubber composition, both natural and synthetic, have now been in use for over 20 years, successfully, under conditions requiring water as a lubricant. These applications include stern-tube and strut bearings of large ships and boats involving shaft diameters from fractions of an inch to more than 2 ft; bearings in pumps, such as deep-well turbines, circulating pumps, dredging pumps, those used for drainage and irrigation, and others. Rubber bearings perform almost unbelievably well at the outermost end of the cutter shafts on hydraulic dredges where they support the rotating cutter as it digs into the bottoms of rivers and harbors. Sand washers and classifiers, and agitators used in many industrial processes employ rubber bearings advantageously. Large rubber guide bearings for hydraulic turbines of 30 to 40 in. shaft diam are being used, some recording continuous service of more than fifteen years' duration.

Careful studies and tests carried out at different times over a period of years by research laboratories of the B. F. Goodrich Company, and observations in service, indicate that these soft-rubber materials, when properly prepared, have the ability to deform and so allow abrasive particles to pass between the resilient surface of the rubber bearing and the revolving shaft with minimum pressure against these surfaces. In other words they do not momentarily carry a large portion of the total bearing load as may be the case with more rigid materials. Moreover, these particles do not embed themselves permanently in a properly compounded soft rubber where they could score the shaft, and consequently abrasive action is to an overwhelming degree nullified. Soft rubber has clearly demonstrated its unique property of wear resistance in many other applications under severe conditions, most common of which of course is the automobile tire.

EXPERIMENTAL WORK REPORTED IN 1932

Experiments conducted some years ago by Dr. W. F. Busse and Mr. W. H. Denton the results of which were published[2] in 1932, demonstrated the behavior of coefficient of friction for soft-rubber bearings under varying ranges of load and speed. Values of less than 0.02 are recorded in these experiments under the conditions of test approximating 300 to 700 fpm, and up to loads of 45 psi of projected bearing area. At these operating speeds and above these ranges, there appears to be no increase in the coefficient of friction with the increase of load. In fact, other experiments made prior to that date, and also since that time, indicate that under some conditions coefficient of friction tends to decrease with increase in load at given speed. Here again the ability of soft rubber to deform serves an excellent purpose in that the bearing surface may adjust itself to minute irregularities in the shaft and so permit the comparatively thin film, characteristic of a low-viscosity lubricant like water, to form and be maintained between the moving surfaces.

Furthermore, in a successful bearing design, featuring a number of longitudinal bearing faces around its inside surface supporting the shaft and separated by water grooves, the flexible nature of rubber allows the faces to deform so as to vary the angle of approach between the bearing and the shaft to correspond to the varying conditions of load and speed, producing an

[2] "Water-Lubricated Soft Rubber Bearing," by W. F. Busse and W. H. Denton, Trans. ASME, vol. 54, 1932, pp. 3–10.

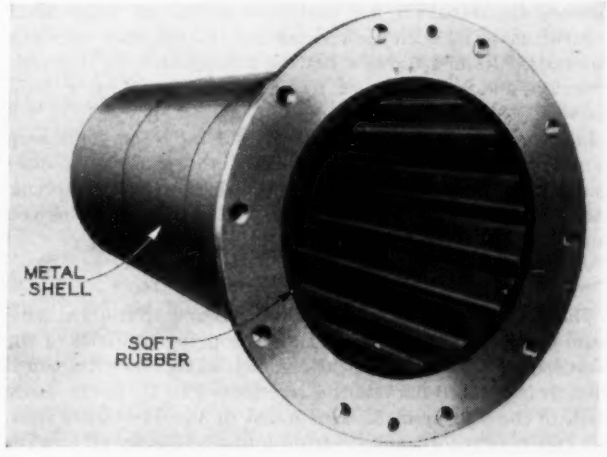

FIG. 1 WATER-LUBRICATED RUBBER BEARING FOR SHIP'S PROPELLER SHAFT, APPROXIMATELY 15 IN. DIAM

Symposium contributed by the Rubber and Plastics Division and presented at the Annual Meeting, Atlantic City, N. J., December 1–5, 1947, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

[1] Lucian Q. Moffitt, Inc., Akron, Ohio.

effect perhaps similar to the action of pivoted segments of modern thrust bearings. This, according to Busse and Denton, probably accounts for the lack of effect of load on the coefficient of friction over the ranges they tested.

The flexible property of rubber provides another advantage on high-speed shafts in that it permits the shaft to turn on its center of gyration when it does not coincide strictly with its geometric center, thus reducing vibration and stresses in the bearing and supporting structure.

HIGH-SPEED APPLICATIONS

The upper limit of speed for water-lubricated rubber bearings has not been determined. Laboratory tests up to approximately 1500 fpm have been made, which would cover most of the common operating ranges. However, on a special racing boat, built in England some years ago for speed-record runs and for races here and abroad, rubber bearings were used for a $1^3/_8$-diam shaft turning at 12,000 rpm, or approximately 4330 fpm. These bearings showed absolutely no distress after having served in various test runs, races, and numerous record runs on this boat.

In continuous service for several years are rubber guide bearings on high-head hydraulic turbines in western states involving shafts 15 in. diam at speeds of more than 500 rpm, or on the order of 2000 fpm.

Like other mechanical devices, rubber bearings require appropriate conditions for proper operation. Shaft journals should be smooth, and consequently reasonably hard corrosion-resistant materials are necessary. Certain grades of bronze, properly processed, and monel metal have been found satisfactory in sea water. Stainless steels and even chrome-plated materials are good in fresh water and in many industrial liquids. Metallized shafts have given good service in some applications, but this method of applying noncorrodible, and at the same time good wearing surface, requires well-experienced operators. Generally, for continuous operation, the bearing should be open at both ends for free circulation of water when submerged, or if the location requires partial or total enclosure of the bearings, provision for circulating water through them should be made. On the other hand, for extremely slow speeds or intermittent service such as rudder pintle bearings, no special provision for water circulation is required even if one end of the bearing is closed.

For natural-rubber compounds oil should be avoided, but recent developments of synthetic compounds for bearings have eliminated this precaution. Tests and service experience indicate that synthetic-rubber compounds promise many worthwhile improvements in other fundamental features of the soft-rubber type of bearing, and this may perhaps be more completely discussed in a future paper.

II—Some General Information About Lignum-Vitae Bearings

By H. V. TOWNSLEY[1]

THERE is a much more interesting aspect to lignum vitae than that of using it as a bearing material. Its commercial use began about 1520, when it was imported into Europe for medicinal purposes. The fact that the splinters from this material which break through the skin will not suppurate or fester, led doctors to believe that it had great healing properties, and for 200 years thereafter it was the main ingredient for medicines; until recent years it was still used as a cure for certain diseases. Because of these alleged healing characteristics, the wood received its name "wood of life." Even today the gum has a place on the apothecary's shelf since it is extracted from the sawdust and added to lard and fatty canned foods to eliminate rancidity.

Some time after lignum vitae was put to use as a medicine, someone discovered the fact that ropes and cables would slide over this material with less resistance than over other woods or materials. Its first use as a bearing material was in ship construction, and it is still used to a considerable extent in ship parts.

Lignum vitae or Guayacum, is a hard dense wood containing an oily resin. The tree is usually found in the tropics and is most abundant in the Island group of the West Indies. It has a specific gravity of 1.35 and weighs 83 to 85 lb per cu ft. From this you can understand why it sinks in water.

HARVESTING AND WORKING LIGNUM VITAE

The tree grows as large as 3 ft in diam and 30 ft high. Because of its great weight and lack of logging facilities in the West Indies, where most of the commercial lignum vitae comes from, it is usual to harvest the tree from 4 to 20 in. in diam. Most of the bearing material is found in 8 to 12-in-diam trees. All logs are cut for transportation into 4 to 6-ft lengths. The cut lumber is not seasoned in the usual sense, and the practice is to measure it by weight and not by board feet as is generally the custom in the lumber industry.

The machines used to cut or shape lignum vitae are a combination of woodworking machines and standard metalworking machine tools. Standard wood-cutting machines are used to rip and cross-cut the logs, but conventional engine lathes, turret lathes, milling machines, and other such tools are employed to form the wood. The technique of machining this very hard dense wood is similar to metal-fabricating processes. High-speed-tool steels for the most part, are used in machining it, although some carbon-steel tools are used. A beginning is being made to use carbide-tipped tools for some applications.

The general machine-shop practice of roughing-out and then finish-machining parts is followed. Bores are normally drilled, bored, and reamed as in metalworking practice. In general, the material machines well. The lubricating gum is no doubt responsible for this. The wood machines better than maple or oak and does not burn or smoke at high machining speeds. Speeds and feeds are in the range of free-cutting brasses and aluminum.

CHARACTERISTICS AS A BEARING MATERIAL

As a bearing material, its chief characteristic or asset is that it does not require lubrication of any kind. The Guaiac gum which forms one third of the material, is an excellent lubricating agent. This gum which gives the wood an oily or greasy feeling at room temperature and yet remains solid, will flow or become liquid when frictional temperature rises above 150 F. which in turn has a tendency to reduce the friction and therefore reduce the temperature. At normal temperatures this gum remains in the bearing indefinitely.

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Under these conditions lignum vitae has a sliding coefficient of friction on steel of 0.16, as determined on an inclined slide without lubricant.

Most liquids when applied to the bearing act as a lubricant in the manner that oil or grease reacts to conventional bearing materials.

Since lignum vitae is a tree, it has growth rings or grain structure as have all other trees. This means that it has a laminated structure, and like most laminates its greatest strength is at right angles to the grain. To the trade this is called "end grain."

End-grain lignum vitae has been known to work successfully as a bearing at pressures of 2000 psi. For this reason heavy-duty bearings are usually made of end-grain sections. Not all lignum-vitae bearings are designed of end-grain materials or segmented sections. Most bearings made from lignum vitae are bushing or solid blocks as in general bearing-design practice.

In general, the proportions used for designing lignum-vitae bearings are those used for designing babbitt bearings. The bearings are designed for working pressures of 75 to 150 psi in the direction of the long grain and as high as 300 psi on the end grain. It should be noted that, because of the large clearances required in wood bearings, the working pressures are actually much higher than the same nominal-size babbitt bearing that is scraped or bored to close dimensions. Lignum-vitae bearings usually will not blue over 20 or 25 per cent of effective bearing area.

Lignum vitae works as well for sliding or reciprocating members as it does for revolving members. It makes good thrust bearings for heavy equipment. It is customary to make large thrust bearings in sections to obtain greater size.

Since lignum vitae does not contaminate, it is an excellent bearing material for use in food machinery and is used extensively for this purpose. It is not attacked by mild acids or brines and thrives very well under conditions where gritty particles are present in liquids. These grits become embedded in the grains of the wood and are then covered over by the gum.

Another characteristic of the material is that it has never been known to score, mark, or wear out the mating journal. Because of its physical makeup, it never seizes, as often happens in metallic bearing materials. In many bearing tests, where the wear of the hole is added to the wear of the shaft or journal, the resultant clearance is usually less than with other bearing materials.

SHORTCOMINGS IN PHYSICAL CHARACTERISTICS

Because lignum vitae is a tree, it has all the deficiencies of a natural material, in that it is not uniform from tree to tree in strength, weight, resin content, or tendency to expand or contract. Like all woods, it will shrink and check. With lignum vitae, this tendency is exaggerated, for not only will the material shrink or expand excessively but it does not shrink uniformly as to direction or amount, and never stops its movement with age, but will always expand and contract noticeably with changes of humidity or temperature.

As an example, a bearing with a $^1/_8$-in. hole and a $^1/_8$-in. wall section will shrink as much as 0.015 in. in a 10-day period following the machining operations. A 3-in-diam bearing with a wall thickness of $^1/_2$ in. will shrink the same amount in the same period. It is easy to understand that the shrinkage will be greater in one direction than in another, because of the laminated structure of the material. Because of the unstable conditions, lignum vitae is only used in bearings or installation where relatively large clearance and large tolerances are permitted. This in turn relegates it to slow-speed applications. In spite of its confinement to the nonprecision-bearing class, lignum vitae still has applications where its ability to perform under adverse conditions without attention or maintenance has made its replacement by its more physically stable competitors almost impossible.

III—Properties and Applications of Laminated Phenolic Bearings

BY L. E. CALDWELL[1] AND JOHN BOYD[2]

THE use of laminated phenolic bearing materials in a wide range of installations over a period of years has shown them to possess important properties which are particularly useful in many applications. The advantages and limitations of these materials, which appear in proper perspective only after prolonged use, have now been fairly definitely determined. The purpose of this paper is to outline and discuss the properties, and certain of the more important applications of these materials.

MANUFACTURING CONSIDERATIONS

Laminated phenolics fall in the general classification of thermosetting plastics. This group of materials includes those which cure, or harden upon the application of heat to form a horny substance which, for practical purposes, will not soften or fuse on further heating.

Phenolic laminations, in general, are made by treating filler sheets of either paper or fabric with a solution of phenolic resin and then carefully heating to remove the solvent and partially set the resin. The resin in this intermediate stage is neither infusible nor wholly soluble. These laminations are then superimposed on one another and subjected to further heating, called curing, to bond them together into a more or less homogeneous mass and to complete the setting or hardening of the resin. In some cases, it is desirable to add other filling materials. These are usually in powdered form and are generally incorporated into the laminated structure by depositing them on the bare filler sheets before treating with resin, or by suspending them in the resin solution before treating. By changing the details of processing and by selecting proper fillers, the properties of the finished material may be varied to meet the requirements of different applications. The methods of handling laminations in the last stages of manufacture are dictated by the type of bearing being made (see Fig. 1).

Laminated phenolic tubing is formed by winding the treated material under tension onto a heated steel mandrel. As each successive layer is wound on, it is bonded by fusing the uncured resin as it passes over heated pressure rolls. The final curing is then carried out on the steel mandrel by one of the following methods: (1) heating in an oven without any additionl external pressure, or (2) molding in a cylindrical mold. When the mandrel is stripped from the cured mass, the rough tubing is ready for finishing operations. The rolled tubing, as produced by the first method of curing, is less dense and has somewhat lower physical properties than the molded tubing produced by the second method, since the only pressure involved in its manufacture is that produced by winding under tension and the shrinkage which occurs during curing. The chief limitation of

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molded tubing is the size and quantity of the equipment required to produce it, and hence the major portion of laminated phenolic tubing is produced by rolling only.

Laminated phenolic plate is produced by curing stacks of the treated laminations between the heated platens of a hydraulic press. In this case, pressures of from 1000 to 2000 psi are applied to the material to produce a mass of maximum density and mechanical strength for a given type of material.

Molded laminated shapes, such as molded radial bearing segments, etc., are in essence curved laminated plate for which the molding surfaces are machined to the correct diameter or shape instead of being flat platens as in the case of flat plate.

The material just referred to as "cured" is at the end point of a chemical reaction accelerated by the application of heat in so far as practical considerations are concerned. Further reaction or cross-linking of the resin molecules can be produced by additional heating, but this reaction proceeds at a very slow rate and in general, does not further improve the properties of the material. The cross-linking of molecules can and will continue, at a much reduced rate at room temperature, giving rise to a slight after-shrinkage of the material. Theoretically, the reaction could continue to the point where all the resin in a given piece became one molecule.

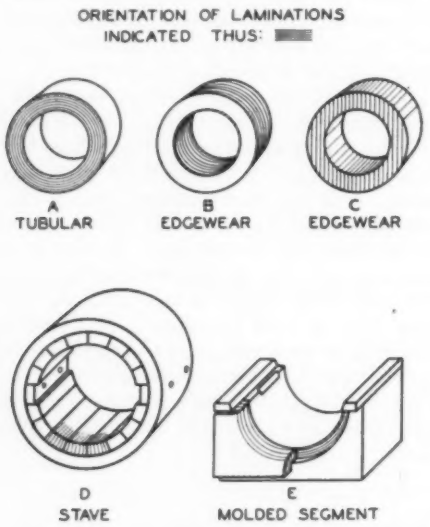

FIG. 1 VARIOUS TYPES OF LAMINATED PHENOLIC BEARINGS

PHYSICAL PROPERTIES

A material manufactured in the foregoing manner exhibits directional properties. In other words, the physical strength of the material depends upon the direction of orientation of the laminations with respect to the applied forces. The greatest tensile strength is obtained when the material is stressed parallel to the laminations, and the greatest compressive, flexural, and impact strengths are produced when the material is loaded perpendicular to the laminations. A somewhat greater Rockwell M hardness is found when measured perpendicular to the laminations than when measured parallel to them. Table 1 lists a number of the physical properties of some of the more common types of laminated bearing materials.

The weights of fabric used affect the physical properties of the various grades of material as may be seen in the table. This is due to several factors, the primary one being the lesser degree of impregnation achieved with the heavier fabrics. Other factors which are less important are the construction of the fabric, such as the tightness of the weave, the twist of the yarn, and the like, and whether the fabric is bleached or unbleached.

Laminated phenolic bearings, depending upon application, employ fabrics ranging in weight from 3 to 50 oz per sq yd of unbleached cloth or belting. The static physical properties of these materials, shown in Table 1, do not have nearly as wide a range as do their dynamic physical properties, as evidenced by their Izod impact strengths.

As may be concluded from the foregoing, the better impregnation and the higher resin percentage obtainable with fine-weave fillers, as compared to that of coarse-weave fillers, determine to a great extent the amount of variation that exists between the various grades. As the percentage of resin used in a laminate

TABLE 1 PHYSICAL PROPERTIES OF LAMINATED PHENOLIC BEARING MATERIALS

Property	Direction[a]	Plate or molded laminated shapes					Rolled tubing		
Fabric weight, oz per sq yd	...	3	6½	8	15	50	3	6½	6½
Resin, per cent	...	60	52½[b]	60	60[b]	40	60	55	60[b]
Specific gravity	...	1.35	1.38	1.38	1.72	1.46	1.30	1.30	1.28
Moisture absorption at saturation, per cent increase in weight	...	3	7	4	6	13			
Tensile strength, psi	WG	7000	11500	11500	9000	7000			
	CG	6000	7000	7000	10000	6000	8500	8000	6500
Elastic modulus, tension, 1000 psi	WG	800	1000	1000	900	600			
	CG	800	600	600	900	600			
Compressive strength, psi	F	40000	36000	37000	38000	32000			
	E	33000	25000	25000	20000	17000	23000	20000	19000
Elastic modulus, compression, 1000 psi	F	500	500	500	700	400			
	E	500	500	400	500	200			
Flexural strength, psi	FWG	17500	18500	19000	15200	12200			
	EWG	15500	17500	18000	14800	11700			
Shear strength, psi	FWG	11000	7000	9500	9200	8400			
	EWG	13000	7000	10500	10100	8500			
Izod impact strength, ft-lb per in. width	FWG	0.8		4	4.7	7.4			
Bond strength, lb[c]	EWG	1600	1200	1600	1900	1700			
Hardness, Rockwell M[d]	F	115	106	112	102	90			
	E	108	98	109	97	74			

[a] G grain (parallel to warp of fabric).
WG with grain.
CG cross grain.
E edgewise (parallel to laminations).
F flatwise (perpendicular to laminations).
EWG edgewise with grain.
FWG flatwise with grain.

[b] Including mineral filler.

[c] Pounds to split 1 in. × 1 in. × ½ high specimen with 1-cm ball.

[d] 100 kg load, ¼ in. ball.

increases, the modulus of elasticity rises. This factor is of importance in applications requiring a minimum of deflection.

OTHER FACTORS AFFECTING USE AS A BEARING MATERIAL

In addition to the physical or structural properties of a prospective bearing material, many other factors must be considered to determine whether a bearing made to a given design from such a material will perform satisfactorily in a given application. In doing this, the bearing, the lubricant, and the journal, rather than just the bearing alone, must be taken into account.

Speaking generally and including other bearing materials as well, it is usually not possible to separate all the factors which contribute to the success or failure of a bearing-lubricant-journal combination into independent variables which can be evaluated specifically. However, certain more or less fundamental requirements may be set down.

In general, such a combination should possess the following: (1) compatibility, (2) stability, (3) adaptability, (4) economy, and (5) any additional special properties required for the application at hand.

These factors determine whether the components will operate together under varying conditions, whether they will resist physical, dimensional, and chemical deterioration, whether they possess the ability to adapt themselves to the usual hazards of operation, and whether their use permits a saving of space, time, or money. These requirements are listed and enlarged upon in Table 2.

Since requirements vary from one application to another and since no bearing combination can excel in all the properties listed in the table, the choice for a given application must be based upon satisfying as many conditions as possible.

The manner in which laminated phenolic bearings, together with various lubricants and journals, measure up to these criteria may be stated as follows:

Compatibility. Laminated phenolic materials inherently possess the property of being able to operate well with steel and bronze journals and with oil, water, or certain other substances as lubricants. Bearings and journals made from such materials show little tendency to weld or adhere to one another. Consequently they have high resistance to seizures.

The hardness of phenolics is ordinarily expressed in terms of the Rockwell M scale and usually runs around 100 (see Table 1). This is equivalent to approximately 40 Brinell, as measured with a 500-kg load. Since the hardness of annealed mild steel is of the order of 115 Brinell (500-kg load), it may be seen that shaft scoring is very unlikely to occur. Usually the journals become well polished in service.

The presence of fillers made from finely powdered hardening agents, used in certain applications such as roll-neck bearings, produces a high finish on the journals.

Although phenolics have a very low thermal conductivity, the important consideration in so far as the bearing combination is concerned is the ability to dissipate frictional heat. Thus by water-flooding, as in roll-neck bearings, large amounts of heat may be removed even though the bearing is made of a rather efficient thermal insulator.

Polishing the journal before it is put into operation helps to reduce the bearing temperatures because it lessens the amount of frictional heat developed. In some water-lubricated bearings, where unusually severe conditions are encountered, it is desirable to use other lubricants along with the water. Many reversing mills, particularly blooming and slabbing mills, show better results when small amounts of grease are injected at regular intervals.

TABLE 2 OTHER REQUIREMENTS FOR A BEARING-LUBRICANT-JOURNAL COMBINATION

Compatibility: Ability of components to operate together under varying conditions		Resistance to seizure and galling at all loads, speeds and temperatures encountered in service. Ability to dissipate frictional heat
Stability: Ability of components to resist deterioration	Physical	Resistance to change in physical properties due to heat, load, load cycle, time, etc. Resistance to fatigue, shock, hammering-out, etc.
	Dimensional	Resistance to wear, swelling, shrinking, warping, etc.
	Chemical	Resistance to corrosion, oxidation, or other reactions between components or adjacent material
Adaptability: Ability of components to adapt themselves to usual hazards of operation		Ability to adjust for slight misalignment, small inaccuracy, etc. Conformability Ability to absorb or eliminate foreign materials. Imbeddability Ability to operate for short periods without lubricant, etc.
Economy:		Economy of space, power loss, initial cost, maintenance, repairs, etc.
Special Properties:		Quiet operation, lightweight, cleanliness of operation, etc.

Stability:

(*a*) *Physical*. Because of their natural resilience, phenolic materials are highly resistant to deterioration resulting from fatigue and shock. They make excellent rudder pintle bushings because they are not hammered out like many other materials under the heavy shock loads.

(*b*) *Dimensional*. The immersion of laminated phenolics in either water or oil does not produce any appreciable change in their mechanical strength. However, since they contain organic fibers which dilate in the presence of certain liquids, slight changes in dimensions may result from contact with the lubricating medium. In the case of lubricating oils, the changes are so slight as to be negligible, but with water or aqueous solution, they are measurable and in some applications must be considered if an adequate design is to be produced. In this connection, it is important to note that the term "per cent moisture absorption," frequently used in describing the properties of laminated materials, does not give an accurate conception of dimensional stability, since it is based on change in weight rather than change in volume.

In general, the finer-weave fabrics produce materials with better dimensional stability because of the smaller amount of moisture which they absorb. Fig. 2 shows the dimensional changes in a marine-grade phenolic material. It will be noted that water produces an expansion of from 2 to 3 per cent perpendicular to the laminations and from 0 to 0.3 per cent parallel to the laminations. The curve also shows the relatively small expansion obtained with oil. The negative slope of the right-hand portion of the curves for 200 F is due to a small superimposed shrinkage caused by maintaining the material at the elevated temperature.

The curves in Fig. 2 are based upon free expansion in all directions. If the material were restrained perpendicular to the laminations, as is the case in some bearings, the expansion parallel to the laminations would be much greater, sometimes as high as 3 per cent.

Phenolics have high wear-resistance qualities and have been found to outlast considerably other materials in many applications.

(*c*) *Chemical*. One of the important characteristics of phenolics is their resistance to chemical attack. They are unaffected by water and oil and are practically uninfluenced by dilute acid and caustic solutions.

Adaptability. Laminated phenolics have a high degree of adaptability. With an elastic modulus of 1×10^6 psi, they are better able to conform to journal inaccuracies and misalignments than babbitt and bronze, which have moduli of 5 and 9 times as large, respectively.

They also possess a high degree of embeddability. This property is employed to advantage on ship stern-tube propeller-shaft bearings, which must operate in water containing sand or sediment.

Economy. Phenolic bearings frequently show considerable power saving because of the relatively low friction obtained. Fig. 3 shows the coefficient of starting friction as a function of load for three types of stern-tube bearings. Fig. 4 shows the coefficient of friction versus rubbing speed for a stern-tube bearing with 40 psi load, and a roll-neck bearing with 4000 psi load. Fig. 5 shows the machine upon which the data for Figs. 3 and 4 were obtained. The design is based upon equipment developed at the Naval Experiment Station.

Actual installations may be expected to show some variation from the foregoing values, depending upon the condition of the journal and bearing surfaces, but in many installations the low coefficient of friction obtained by water lubrication has resulted in considerable power saving compared to metal bearings. Part of this saving can be attributed to better bearing practice, but much of it results from the characteristics of the material.

An important feature of stave-type phenolic bearings (see Fig. 1) is the ease with which spare or repair parts may be stored and fitted.

Special Properties. Since conditions sometimes establish unusual requirements, the need for bearing combinations with special properties is often encountered. A single example will illustrate the point.

In order to prevent the noise and vibration from streetcar trucks being transmitted to the car body, a bolster bearing having noise-deadening characteristics was required. The problem was satisfactorily solved by the use of laminated phenolic bolster cup bearings (see Fig. 6).

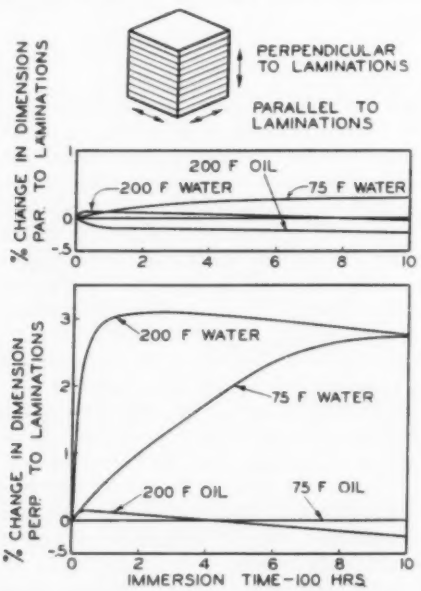

FIG. 2 DIMENSIONAL CHANGES IN MARINE-GRADE LAMINATED PHENOLIC MATERIAL DUE TO WATER AND TO OIL IMMERSION

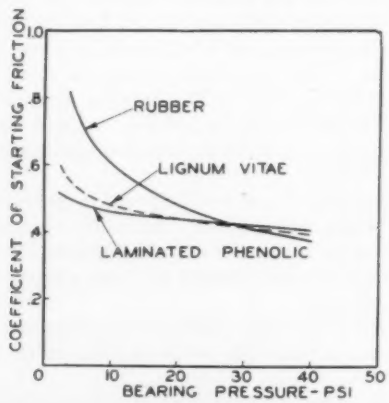

FIG. 3 EFFECT OF BEARING PRESSURE ON THE COEFFICIENT OF STARTING FRICTION, 6-IN-DIAM × 12-IN-LONG STERN-TUBE BEARINGS

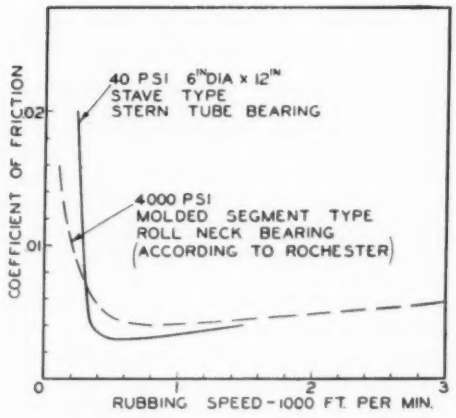
COEFFICIENT OF FRICTION
40 PSI 6"DIA x 12" STAVE TYPE STERN TUBE BEARING
4000 PSI MOLDED SEGMENT TYPE ROLL NECK BEARING (ACCORDING TO ROCHESTER)
RUBBING SPEED-1000 FT. PER MIN.

FIG. 4 COEFFICIENT OF FRICTION VERSUS RUBBING SPEED; WATER-LUBRICATED LAMINATED PHENOLIC STERN-TUBE AND ROLL-NECK BEARINGS

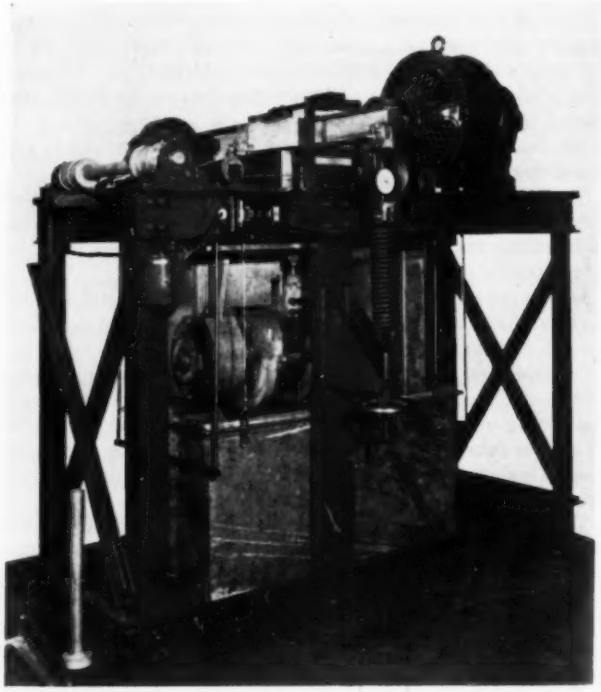

FIG. 5 STERN-TUBE-BEARING TESTING MACHINE

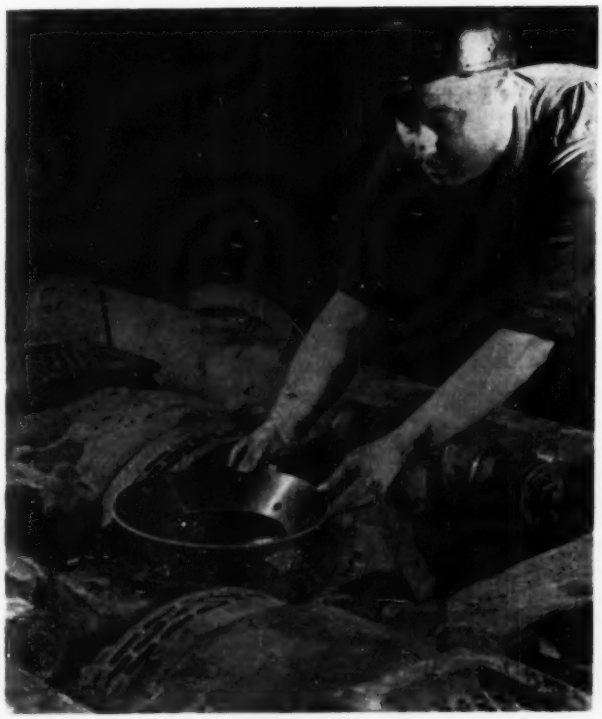

FIG. 6 LAMINATED BOLSTER CUP BEARING FOR P.C.C. CAR; 12 IN. OD

FIG. 7 LAMINATED RUDDER-STOCK BEARINGS FOR CARGO VESSELS; 18 IN. ID

TYPES OF LAMINATED PHENOLIC BEARINGS

The types of construction used for laminated phenolic bearings is determined primarily by the kind of service to which they will be subjected. Secondary considerations are, of course, manufacturing facilities, interpreted in the light of the number of identical pieces required. The main types are shown in Fig. 1.

Tubular bearings (type A) are machined from laminated tubing stock. They are used principally under conditions requiring a complete bushing. They are available in any size up to 48 in. ID (see Fig. 7).

Edgewear bearings (types B and C) are machined from laminated plate stock. They are intended for light-duty service. Type B bearings are normally 2 in. or less in length and are generally used as guide bearings.

Type C bearings are also machined from plate stock. They are available up to 3 in. ID in any length that is practical to bore and are used primarily for small-craft stern-tube bearings.

Stave bearings (type D) are fabricated from laminated plate stock and can be made in any size from 3 in. ID up. They are

FIG. 8 LAMINATED STERN-TUBE BEARING INSTALLED IN A CARGO VESSEL; 15 IN. ID

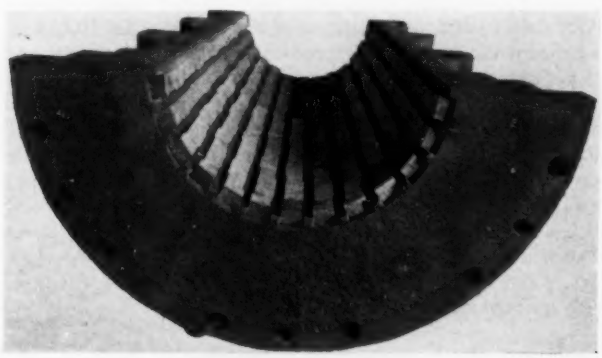

FIG. 9 LAMINATED GUIDE BEARING FOR WATER-WHEEL TURBINE; 24 IN. ID
(One half of bearing shown.)

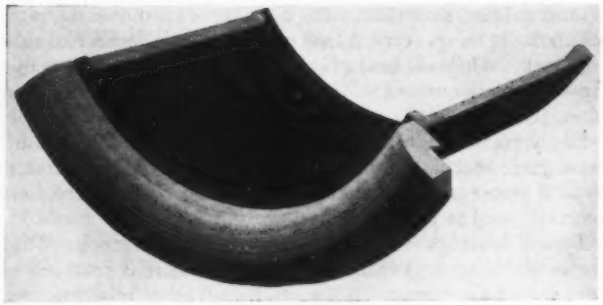

FIG. 10 LAMINATED ROLL-NECK BEARING FOR THREE-HIGH BREAKDOWN MILL; 22 IN. ID

used mainly for stern-tube and rudder-stock bearings on ships and for guide bearings on vertical water-wheel turbines (see Figs. 8 and 9).

Molded segment bearings (type E) are molded to size. They are normally used in conjunction with a thrust plate which can be either molded or fabricated from plate stock. They find their greatest use as roll-neck bearings in the steel industry (Fig. 10).

BEARING CLEARANCE

In establishing the clearance which should be provided when machining a laminated phenolic bearing, it is necessary to consider the actual running clearance desired and the additional clearance necessary to compensate for any swelling that may take place after machining.

In the case of partial or open-face bearings (bearings with less than 180-deg arc, such as roll-neck bearings), it is usually unnecessary to make any allowance for swelling in determining the clearance.

In the case of full- or bushing-type bearings (bearings which completely surround the journal), however, it is essential that swelling be taken into account. A consideration of the design of a marine stave-type stern-tube bearing will illustrate the manner in which this is done.

Since such bearings usually have low bearing pressures (of the order of 25 psi), the staves are installed so that the load is carried on the edge of the laminations rather than flatwise. This construction gives more uniform wear properties.

In installing the staves, it is desirable to machine the individual pieces and to bore the assembled bearing dry, thereby eliminating the difficulties attendant upon saturating the phenolic material and keeping it saturated until ready for use.

If the staves in a 6-in. stern-tube bearing with $^1/_8$-in-thick staves, were to swell freely, the circumference would increase about 0.6 in., and the thickness of the staves about 0.0015 in. (3 per cent tangentially, perpendicular to the laminations and 0.3 per cent radially parallel to the laminations).

In order to keep the radial swelling as small as possible and to make removal of the shell from the housing easier by minimizing the shell distortion due to swelling forces, stern-tube bearings are usually fitted with elastic or spring staves as shown in Fig. 11. These staves absorb the circumferential swelling with a minimum of resulting force and permit the installation of such bearings with small clearance allowance for swelling. Figs. 9 and 12 show a slotted shell in which each slot is fitted with its own spring stave.

ROLL-NECK BEARINGS

The first development work on laminated phenolic roll-neck bearing material was carried out on a medium-weave (12-oz per sq yd) fabric. In the early trials, the material was more or less naturally turned on edge in the same manner as the lignum vitae it was being used to replace. The first application was on a rod mill. It was found that the bearing worked satisfactorily with water lubrication, and additional installations were made with the same results until the bearing pressures became too great for this on-edge type of construction. Trials were then made with the same material turned flatwise in order to take advantage of the greater compressive strength of the material only to find that with the same loading and speed conditions the material would blister as the result of local overheating.

This objection to flatwise-constructed laminated phenolic bearings was first overcome by the use of heavy fabrics. The fabrics (30 to 50 oz) used were woven in such a manner as to present ends of some threads in the bearing surface. This, in effect, gave a partial edge-grain surface with the strength of flatwise construction. The explanation of the difference between the edge-grain and flatwise operating characteristics is that the former more readily allows the escape of gases produced under the surface by local overheating than does the latter. Needless to say, such overheating is a self-aggravating condition once it has started and, if the temperature reaches the point at which gases or steam are produced and trapped beneath the surface, the degree of self-aggravation increases to the point of severe heating and failure.

The heavy-weave materials will carry high loads even at slow

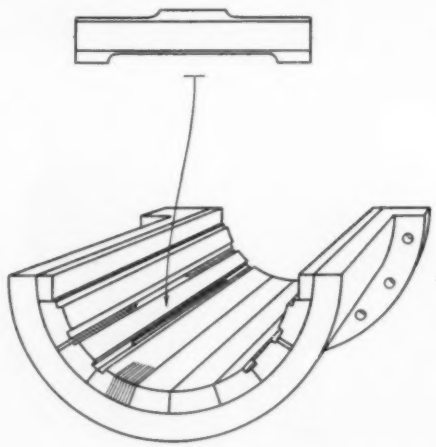

FIG. 11 SOLID-PACKED STERN-TUBE BEARING SHOWING SPRING STAVE

FIG. 12 SLOTTED-SHELL STERN-TUBE BEARING FITTED WITH SPRING STAVES

TABLE 3 TYPICAL LAMINATED PHENOLIC BEARING APPLICATIONS

Bearing application	Type[a]	Size range, in.	Fabric weight, oz per yd	Resin, per cent	Lubricant	Diametrical clearance, in.[b]	Principal reasons for using laminated phenolic bearing material
Roll-neck bearing	E	3–30	15–50	40–60	Water or emulsion	0–1/2	Longer life—power saving due to lower friction—lower-cost water lubrication—greater cleanliness of operation—better holding of gage due to less wear
Ship stern-tube bearing	D	3–26	8	60	Water	0.001 per in. diam. over 5 in. diam.	Longer life—greater ease of handling and installing—higher load capacity, particularly with impact loads—lower friction—greater corrosion and decay resistance—lower journal wear—greater local availability
Ship rudder-stock. Pintle bearing	A, D	3–36	3–8	55–60	Grease, water	0.001 per in. diam. over 5 in. diam.	
Small-craft stern-tube bearing	C	1/2–3	8	60	Water	0.005	
Centrifugal pump bearing	A, B, C	1/2–4	3–8	60	Liquid pumped	0.005	Longer life—better lubrication with liquid (water, gasoline, chemical solutions, etc.) pumped
Water-wheel turbine guide bearing	D	4–24	8	60	Water	0.005	Longer life—lower friction—no decay—less journal wear
Ball-mill bearing	A, E	15–48	6 1/2–15	55–60	Water, emulsion, water and grease	0.015–0.030	Longer life—higher load capacity—lower friction—lower lubricant cost
Aircraft landing-gear bearing	A	2–15	3	60	Oil	0.001 per in. diam. over 5 in. diam.	Lighter weight—satisfactory dimensional stability and load capacity
Railway bolster-cup bearing	Molded cone	...	6 1/2	53	Grease	...	Longer life—lower noise and vibration transmission

[a] See Fig. 1. [b] Running clearance; does not include allowance for swelling.

speeds and will also withstand severe impact loading without the hammering-out experienced with babbitt. Under such service as is experienced in blooming, slabbing, and some roughing-mill service, they still give the best performance of any of the laminated bearing materials available. However, as a result of their comparatively low resin percentage, their rate of wear is relatively great after the initial hard surface is worn off.

The next step in the development was the addition of graphite as a mineral filler to the materials already available. This lowered the degree of bonding between the laminations and consequently produced a somewhat softer material with correspondingly lowered strength. These materials have proved satisfactory for some applications.

After the graphite materials were tried, other mineral fillers which would increase the abrasion resistance of the laminated materials were introduced. It was found that medium-weave (12-oz) fabric laminates, including finely powdered hardening agents, when applied flatwise would give much better service in roll-neck bearings operating at 200 or more ft per min than did any of the previous laminates tried. Below 200 fpm slip velocity these materials show a tendency to overheat and seize, but at speeds great enough to bring sufficient cooling water to the bearing surface, they polish or lap the journal surface to a high finish and thereby lower the operating coefficient of friction below that of straight laminates. Such bearings require a larger quantity of cooling water than do the other grades of materials. Where operating conditions permit their use and a slight amount of journal wear is not objectionable, they give the best service of any laminated phenolic material available.

Table 3 is useful in illustrating how the advantages of laminated phenolic materials are applied and their limitations taken into account in a number of typical bearing applications.

CONCLUSIONS

The foregoing discussion has attempted to describe the properties of laminated phenolics as bearing materials. Their limitations will, of course, exclude many applications, but their numerous advantages will undoubtedly widen their present fields of application.

IV—Reduction of Wear in Rubber Stern Bearings by Flow-Controlled Continuous-Film Method

By R. D. SMEALLIE[1]

DURING the recent war, landing-craft propeller-shaft bearings and shafting were a costly and time-consuming maintenance problem. In peacetime, the condition is paralleled in many parts of the world where vessels are forced to operate in shallow waters heavily laden with sand, silt, coal screenings, and coral, all of which are conducive to excessive shaft or shaft-liner and bearing wear.

In attacking the problem of minimizing maintenance from this natural hazard, it became apparent at once, that, not only was a complete mechanical change inevitable, but the technique of lubrication also must be overhauled to increase greatly the sand-ejection rate within the bearing.

The first mechanical change toward the objective was an important step in shaft conservation and consisted of combining the shaft sleeve and bearing as an integral one-piece unit. In pursuing this step, the shaft sleeve with its molded rubber covering was locked to and rotated with the shaft, the "rotary journal" using for its opposite frictional surface a stationary

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renewable bronze bushing. This type of rubber bearing, although not of a continuous-film construction at that time was used successfully throughout the war for propeller-shaft bearings on landing craft.

The next step was based on a study of hydrodynamics which brought to light a little-used law of physics involving action of a submerged shaft rotating under water at various loads and speeds.

As a result of the study, it was determined that the internal action of a submerged bearing took on a definite pattern of a vacuum-pressure cycle which when analyzed was observed to set up a dual action of pressure and vacuum for each 180 deg of a revolution. This double cycle has now been developed to produce several characteristics which heretofore seem to have been entirely neglected in the design of marine stern bearings. It became clear that the primary requisite was to block all film "pressure escape points" having their origin within the loaded section of the bearing. The first apparent advantage was the formation of a "continuous" lubrication film which, in effect, allowed the build-up of a perfect water wedge. This was highly desirable inasmuch as it afforded a very high degree of "shaft flotation." Separating the frictional surfaces by this uninterrupted water wedge reduced materially the coefficient of friction at practically all speeds with particular emphasis at low speed where shaft and bearing damage is at its most critical point.

A definite proof of complete shaft flotation was evidenced by the fact that, instead of the maximum-wear point being 12 to 15 deg ahead of dead center (in direction of rotation), the effected water wedge had actually picked up the shaft and changed its maximum point of wear to approximately 15 deg after passing through dead center. Thus a change of nearly 30 deg took place in the maximum-wear point between the continuous-film and noncontinuous-film method of lubrication.

Following further reactive results, it was found that as soon as the shaft speed was sufficiently high to effect shaft flotation, an important and pronounced sequence occurred. For example, assuming a point diametrically opposite the maximum load, the generated film pressure between frictional surfaces was zero. Progressing in the direction of rotation, consecutive readings taken on a compound gage showed increasing pressure until it arrived at its greatest value directly in the maximum loaded area. This action is a long-recognized lubrication fundamental which has been disregarded, almost without exception, in the present-day design of stern bearings.

Passing through the next 180-deg cycle, the pressure, within a few degrees after having passed through the maximum loaded area, had reverted to a maximum vacuum which decreased in the direction of rotation until it subsided completely at the original starting point. This dual cycle was repeated on each revolution of the shaft and merely reversed the pattern of action when the shaft was rotated in the opposite direction.

The following step, however, was an entirely new conception of rapid sand removal and a direct result of applying theories known to exist in the double pressure-vacuum cycle briefly described.

PUTTING THE PRESSURE-VACUUM CYCLE TO WORK

By placing two axial-flow control grooves running from end to end on the inside periphery of the mating bronze bushing, one in the pressure area and one in the vacuum area, advantage was taken of the hydrodynamically developed pressure and vacuum values. Sand and water were taken in on the vacuum cycle while sand and water were also discharged under pressure during the pressure cycle. Both actions are continuous, once the shaft is rotating, and will duplicate the action in either direction of rotation.

Part of the phenomenon occurring in the action somewhat defies a clear mathematical explanation inasmuch as the water flow in the pressure-control groove is a right-angle component of the circumferential water flow. Existing proof of the action may be cited when water levels are dropped to the center line of the bearing at which point water can be observed being ejected from the pressure groove with considerable force while the vacuum grooves of course show no discharge. When testing large bearings, the vacuum action becomes sufficiently violent to draw a person's hand against the intake area at the ends of the bearing.

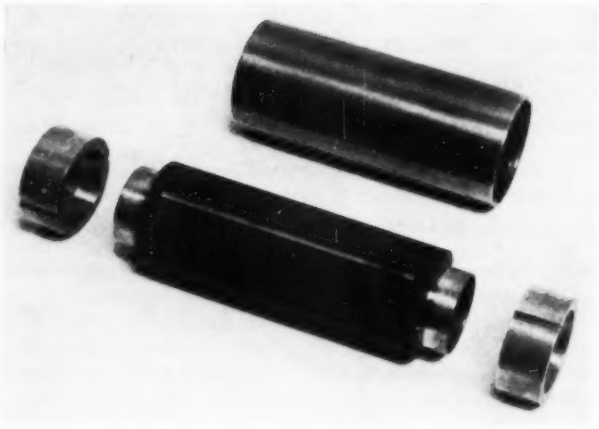

FIG. 1 ROTARY RUBBER BEARING

One of the outstanding characteristics of the continuous-film method is its reduced low speed coefficient of friction. For example, at 100 rpm with a load of 30 psi, the frictional torque is 50 per cent less than for the interrupted-film method. Frictional horsepower, by the same token, has a ratio of 2 to 1 in favor of the continuous-film method.

To contribute further to low frictional characteristics at low speeds, axial water traps or reservoirs are designed in the form of molded grooves placed in the rotary rubber journal. The grooves in the rubber tend to supply a constant source of additional water under pressure regardless of how slowly the shaft may rotate. The slow-speed grooves are blocked at both ends to prevent water and film pressure escape through the ends of the rotor grooves while operating in the loaded area.

TESTS DEMONSTRATE ADVANTAGES

Considering the four major factors of design, continuous-film lubrication, automatic sand ejection, slow-speed water feed, and shaft conservation, the results manifested themselves very effectively at the end of 72-hr destructive tests. The depth of scouring in the metal bushing took on an even depth which was approximately 70 per cent shallower than for the noncontinuous-film type, score lines being barely perceptible to the fingernail. When running parallel tests on several types of interrupted-film nonflow control-type bearings, the wear progressed through to the housing, causing the test to be discontinued as inoperative. The continuous-film flow-controlled bearing still had 42 per cent life remaining, practically all wear being taken on the renewable metal bushing and less than 0.001 in. on the rubber. Because of its integral rubber-covered shaft sleeve, the shaft was preserved in its original state.

Continuous-film lubrication is of unquestionable engineering value and has been used for many years in the operation of high-speed turbine bearings, reduction-gear units, and for various heavy-duty industrial bearing uses. This method of lubrication, combined with automatic sand ejection, slow-speed water feed to frictional surfaces, and complete preservation of shafting, bids fair to the establishment of a new low in maintenance costs.

The Importance of CORES *in* DIE-CASTING DESIGN

By C. R. MAXON

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WHEN it has been decided from the size, complexity, and estimated cost of a part that die casting is the logical production method, the designer is still faced with numerous problems in the design of the casting. If the designer proceeds without enlisting the aid of a die caster, he may find that die cost, casting rates, flash-removal problems, and other possible savings may have been overlooked. To avoid these penalties of inexperience, it is advisable to consult a die-casting engineer before the form of the part has been established and to check the design against possible violations of die-casting principles.

Space permits comprehensive discussion of only one aspect of die casting, namely, practical considerations involved in the design of cores.

The designer should bear in mind that die castings are made in metal dies. These dies are not scrapped of course after each casting, as sand molds are, but are long-lived and last for many thousands or even millions of fillings.

As dies, including cores and slides when needed, are rigid structures, the designer of the casting may well try to visualize the casting in such a die and then consider what must be done to fill the die, and what is needed to get the frozen casting out of the die expeditiously without injury to either die or casting.

Once such a picture is clearly in mind, it is easy to grasp many of those practical considerations on which a logical design is based. The designer of the casting seldom designs the die, but he can easily appreciate, upon reflection or conference with a die caster, what a particular design will involve, especially in respect to parts of the die which must have relative motion.

Both the value and general utility of die castings are greatly enhanced because of the facility and precision with which coring can be done. This is evident when the following advantages of coring are stated:

1 Substantial savings in the weight of the casting.
2 Provision of holes and recesses within close limits as to size and location.
3 Uniform sections.
4 Sound castings.
5 Shorter casting cycle, resulting from faster cooling.
6 Decreased machining time and cost.

Several of these advantages are not attained at all or only in much more limited degree in sand castings and are partly responsible in most cases for making die castings less costly than the nearest sand-cast equivalent. For sand castings, the core must usually be made separately and placed in the mold, and the mold is always destroyed after the casting is produced. It is difficult to hold close dimensions with sand cores, and they often shift in the mold so that the hole or recess is not correctly located.

In contrast, the cores for die castings often have a life as long as that of the die itself. Moreover, their size is subject to little or no change, hence the hole or recess formed is held closely to size and changes in location are slight. Naturally, this greatly reduces and frequently eliminates machine work on the hole or recess.

In addition, many holes that are readily cored in die castings are too small in size to be cored at all in sand castings. In die castings, cored holes are precisely located and often can be held to tapping size. In occasional instances, a threaded core can be used and then even tapping is avoided.

There are of course many cases in which small holes needed in die castings cannot be cored as cheaply as they can be drilled or pierced, but even then a conical spotting core often can be used to locate the drill. As flash is left in through-holes that are cored and generally must be removed subsequently by a drill or punch, it is often cheaper to drill or pierce than to core such a hole.

Where a hole or recess is needed and can be cored, there is not only a saving in metal but the metal saved does not have to be cut away and remelted. Moreover, by avoiding concentrations of metal, especially at bosses, sections can be made more nearly uniform in thickness. This means faster cooling in the die and sounder castings, for porosity is prone to occur where sections are thicker locally than those of adjacent sections.

TYPES OF CORES AND APPLICATION

Simple Forms of Cores. The simplest core is a pin cylindrical in shape, except for such draft as is required for its withdrawal. Such a core costs little to machine. Its shank, which fits a hole in the die and does not come in direct contact with the metal to be cast, is a true cylinder and so fits a hole which is easily drilled, bored, and ground. In general, the shanks of cores are made cylindrical even though the part that is to form a hole in the casting is not of circular section, as this facilitates machining of the shank and of the hole in which it fits.

Cores can have any required shape as long as they can be removed from the casting. They often include flats or extensions, such as to form keyways. However, shapes that are easy to machine are preferred. If the core has to be movable in reference to the die, a sliding fit is required and, if a noncircular hole is needed in the die, broaching or its equivalent may be necessary with the possibility of a considerable increase in machining cost, although its cost may be fully warranted by savings in machining on the castings produced.

Cores that are fixed in the die are not only cheaper but result in less flash. Some flash always occurs around movable cores because some metal is forced into the clearance space required between the core and the die. This flash, often in the form of an irregular collar, may be slight but generally has to be removed in a light machining operation.

Fixed cores can be used, in general, only when their axes are parallel to the motion of the die or of a slide that supports the core. If the core is disposed at an odd angle and is not on a slide moving at that angle, it must always be made movable.

Movable Cores. Movable cores are commonly applied but means for actuating them must be provided, and they must be locked when the die is closed so that the pressure on the metal

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does not force them out of position. Consequently, application of a movable core adds considerably to die cost and usually increases the cost per casting to some degree. However, these disadvantages are more than offset by benefits on other scores, else the cores would not be used.

Among the advantages of some movable cores (aside from the fact that they provide holes or recesses where they are needed) is that the clearance around the core permits the escape, from the die, of air that might be trapped otherwise and result in porosity which would prove detrimental. Although the details of core design are commonly left to the die designer, some knowledge of what cores involve in respect to cost can often aid the designer of the casting to minimize over-all costs.

Core Actuation. The commonest way to actuate a core is by a rack and pinion or by a plate back of the ejector portion of the die. Many cores are arranged to come in the die parting, partly because this location sometimes facilitates the machining of surfaces which position and guide the core. Pinions for rack-operated cores are often turned by hand but some part of the machine or of the die can often be so arranged that operation becomes automatic and saves time.

FIG. 1 CASTING WITH UNDERCUT RECESS FORMED BY A ROCKING CORE

FIG. 2 UNDERCUT PRODUCED BY CORE WITHOUT KNOCKOUT OR COLLAPSIBLE FEATURES

Any core that requires motion in the die must be so placed that it can be withdrawn, usually before the die opens. If the travel is greater than can be provided parallel to die motion, the die must be designed for a side or angular pull.

When a movable core is required to form a thread, means for rotating the core must be provided. For a product requiring a helical spline or thread of extremely coarse pitch or one involving a helical gear, the core can be fixed axially but arranged so that it can turn as the part is ejected off the core.

Intersecting Cores. Cores that are brought together or that even interlock when the die is closed are feasible and sometimes are exceptionally useful but they do introduce problems in die-making, casting, and flash removal. Flash always forms where cores join and, if this flash is inaccessible, its removal may add considerably to the cost per casting. On the other hand, the advantages realized by such coring frequently outweigh the drawbacks.

If cores actually interlock, they must be operated in correct sequence as otherwise breakage will result and expensive replacement may be needed. It is best to avoid interlocking cores unless the expense of making core operation fully automatic is justified by corresponding economies or other compensating advantages.

Collapsible Cores and "Knockouts." In general, a solid one-piece core cannot form an undercut, because this will prevent its removal from the casting. If the core can be curved and rocked through an arc, it can form an undercut and still be made in one piece, although this involves expensive die construction. Fig. 1 shows a casting that has an undercut recess formed by a rocking core.

An unusual case in which a core produces an undercut without resort to a knockout or to collapsible features is shown in Fig. 2. The main core for this casting is made in two sections, one fixed and one movable. The movable one produces a recess back of a lip and, instead of being withdrawn before the casting is ejected, is advanced and acts as an ejector along with normal ejector pins through the fixed core. When well out of the die cavity, the casting is struck a light upward blow directed parallel to the die parting. This lifts the casting free of the "hook" or side projection of the movable core and frees it from the latter. This might be termed "two-directional" ejection.

Collapsible cores are feasible in some cases but they are expensive and frequently they involve high die-maintenance costs and may make flash-removal costs rather high. Collapsible cores must not only be capable of collapsing but must include a mechanism to withdraw the collapsing parts and to expand them for the next casting. This means that the main core must be of sufficient size to hold the collapsing elements and at least a part of their operating mechanism. To warrant this expense, the results secured should be such that they cannot be attained more cheaply by machining, by some feasible change in design, or by the use of "knockouts."

Knockouts are really loose cores which, instead of being withdrawn from the casting before or at the time it is ejected from the die, remain in the casting until it has been removed from the die. Then these loose pieces are knocked out and are set into the die for each subsequent casting. Often two or more sets of such inserts are provided so that one set can be placed in the die and a casting made while another set is being knocked out from a casting previously made. All knockouts have to be placed and held securely in the die, slowing the casting cycle and frequently requiring extra labor. For these reasons, die casters prefer not to use loose pieces unless the required results are otherwise unobtainable. Loose pieces also add both to the initial and maintenance costs of dies and always result in some

extra flash which increases the cost of cleaning castings. An example of loose-piece cores is illustrated in Fig. 3. Here a loose piece, set into the major core, provides an undercut recess. The flash line around the joints that the loose piece makes is apparent but flash is easily removed.

Metal-Saving Cores. In many castings there are portions in which holes or recesses are not required to serve a definite function but are desirable both to reduce the weight of the casting and to avoid having certain sections thicker than they need be. Such holes and recesses are produced by cores that are termed "metal savers," and their use does effect economies in metal, besides helping to avoid porosity. By avoiding metal concentrations, metal savers help promote rapid cooling of the casting, so that the die can be opened sooner and cycle time can be reduced. The chance of shrink marks is also reduced when metal concentrations are avoided.

All cores save metal whether used primarily for that purpose or to produce holes or recesses having other functions. Cores have to be varied in shape of course, to meet specific requirements, but the cost of the core is minimized when its shape is as simple as conditions permit. If this fact is kept in mind by the designer, he can help to lower finished-casting costs.

Although the casting shown from both sides in Fig. 4 has three tubular extensions and numerous bosses, cored recesses and holes from both faces and between the bottom flange and the housing, as well as through the flange, help to avoid thick sections and to keep them relatively uniform in thickness. There is no needless excess of metal at any point because of the skillful use of metal-saving cores.

SIZES OF CORES

Although cores as small as $^1/_{32}$ in. diam are sometimes used, especially in die-casting zinc and other low-melting alloys, smaller cores are not often recommended unless very short. Even then it is often better to drill or pierce the hole. In all cases, cores should be sturdy enough to avoid bending, breaking, or "burning." The latter is caused by attack of the molten alloy, which, at high temperatures, has an erosive effect that makes for rapid deterioration and may necessitate frequent replacement of the core with consequent production delays. Cores of less than $^3/_{32}$ in. diam are rarely advised for high-melting alloys and then should be quite short.

Unless very small, cores which have a length up to four diameters are feasible, as a rule. Cores of $^1/_2$ in. or larger diameter are often made many more times their diameter, depending upon the specific design and the alloy being cast. Holes too small or too long to be cored to full depth can often be cored to part of their depth and then be drilled the remaining depth and still effect economies. Cores which are supported at both ends are stronger than if supported at one end only, but cores piloted at their outer end may add somewhat to flash-removal problems.

Cores are often heavily stressed by the shrinkage of the casting in cooling and, especially when minimum draft is allowed or particularly when the metal "solders" to the core, may be broken by the stress applied when the core is pulled or when the casting is forced off the core at ejection. All these considerations tend to favor the sturdy core, but there are cases where unusually slender cores are feasible and effect savings more than compensating for such difficulties as their use incurs.

The minimum diameter of cores for use with aluminum alloys is about $^3/_{32}$ in. and for copper alloys is about $^1/_8$ in. For zinc and the other low-melting alloys, cores down to about 0.040 in. diam are sometimes used.

DRAFT ON CORES

In general, the draft on cores is preferably not less than $^1/_2$ deg on a side. Draft can be less, especially for zinc and other low-melting alloys, if the core is not too long or too slender. Cores having no draft have been used in some zinc die castings but should not be specified unless the die caster consents, as it is likely to be preferable to use some draft and size the hole by reaming or broaching if necessary.

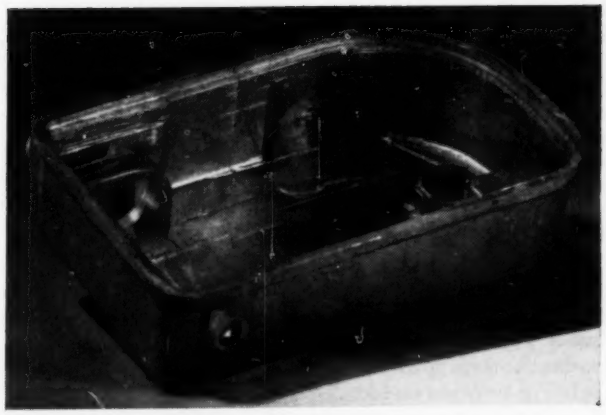


FIG. 3 AN EXAMPLE OF LOOSE-PIECE CORES

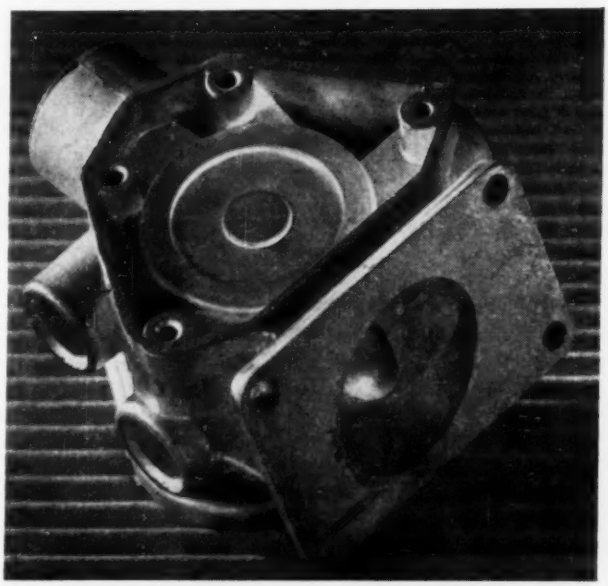


FIG. 4 CORED RECESSES AND HOLES HELP AVOID THICK AND NON-UNIFORM SECTIONS

Where a taper of 1 deg or more on a side is permissible, it is well to so indicate, as this may make the casting easier to eject from the die. If less pressure on ejection pins is thereby attained they will mark the casting less deeply. The chance of distorting the casting because of the pressure may also be reduced. Core taper should not be so great, however, as to necessitate unduly deep cuts in holes to be machined or to require extra machine operations which add to over-all cost without a compensating advantage.

Fixed cores that form "blind" holes do not result in extra flash, but all movable cores leave some flash at one or both ends of the hole. Fixed cores which form through-holes leave flash at the outer end of the hole. Collapsible cores and knockouts result in considerable extra flash, as already explained. In general, a simple and rapid drilling, punching, facing, or countersinking operation cuts the flash from the ends of cored holes but some time and tool use are involved. The cost must

be added to that of the casting itself. This cost detracts but little from the benefits which are brought about by coring.

From the foregoing it is apparent that cores, although they involve certain problems, also have utility such that the benefits realized commonly much more than offset whatever disadvantages they entail. This becomes still more apparent upon consideration of some uncommon applications and features of coring with which designers of die castings should be familiar.

EXAMPLES OF CORING

Although thin flat cores sometimes tend to give trouble from warpage, they can be used if not too long, as seen in the zinc die casting, Fig. 5, which has a cored slot only 0.015 in. thick and about $^1/_2$ in. deep. The core for this slot is in the die parting and so must be made movable. It appears to have slight if any draft.

In Fig. 6 are shown four castings which are produced hollow by the use of cores that are rocked into and out of place. One of the elbows is in aluminum alloy but the other castings are in zinc alloy. The two elbows at the bottom have cores that make a 90-deg bend and measure $^{23}/_{32}$ in. at the small end and $1^3/_{32}$ in. at the large end. Because of the fairly large draft, withdrawal is simplified.

In producing the flanged elbow, shown in the center, the major core is made in two pieces, one of which forms a 90-deg bend and so has to be rocked into and out of place. Its small end is $^3/_4$ in. diam and its larger end, at the small flange, is $^7/_8$ in. diam, affording plenty of draft. The other portion of the main core is $^3/_4$ in. diam at its inner end and forms a $^{25}/_{32}$-in. hole at

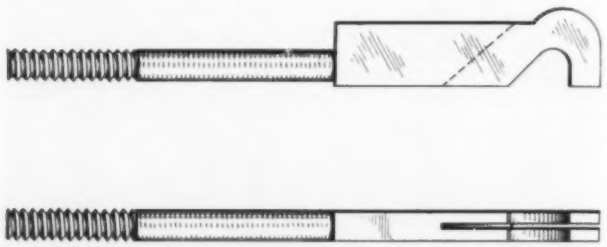


FIG. 5 USE OF THIN FLAT CORE

FIG. 6 HOLLOW CASTINGS PRODUCED BY CORES ROCKED INTO AND OUT OF PLACE

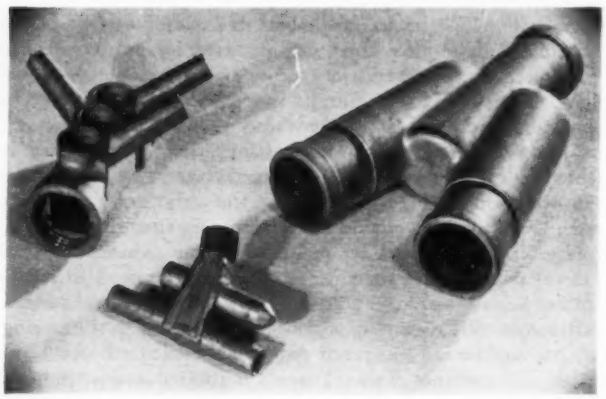


FIG. 7 CASTINGS WITH CORED HOLE AT ODD ANGLE

the flange end, again providing plenty of draft. Both these cores are movable and have their axes in the die parting.

Four small cores produce $^7/_{32}$-in. through-holes in the large flange, and a $^3/_{32}$-in. blind hole is cored near the pointed end of this flange. A sixth cored hole of arc-shape section is cored through a boss projecting from the face of this flange, the core tapering to a rounded point. This core is in line with a boss back of and parallel to the flange having a cored $^1/_8$-in hole.

The face of the large flange is formed by a slide in the die, and all holes at right angles to the face are formed by cores attached to the end of the slide and arranged to move with it. Two holes are required through the small flange, and the face of this flange is formed by the core. However, as the core rocks it cannot include straight pins to form the holes through the flange, so the holes are merely spotted by short conical projections on the face forming the flange. This spotting locates the drill used to make the flange holes, hence no drill jig is needed.

At the top of Fig. 6 is a phonograph tone arm, having a ram's-horn shape, but the cored hole tapers regularly from $1^1/_4$ in. at the large end to $^5/_8$ in. at the small end, its center line following a true helix, $3^1/_2$ in. diam and $7^1/_4$ in. pitch. This makes it possible to use a one-piece core which is given a combined turning and longitudinal movement when being rocked out of the large end of the casting. This is a most unusual coring job, but the die and core were reported in excellent condition after 40,000 castings had been produced. The wall section of the casting tapers from about 0.110 to 0.080 in.

All three castings in Fig. 7 have cored holes at odd angles. In the largest casting, the cores are all $^7/_8$ in. diam at their large ends, have only slight draft, and all have their axes in the parting plane. Flash, where the cores join, is somewhat inaccessible, but not to the extent that, by the use of suitable burring tools, the flash cannot be removed without undue cost.

The casting which includes three small tubes extending at odd angles from a square body has its main hole formed by a square core pin. At right angles to the main core are three step-cored vertical holes. Each of the thin-wall tubes projecting at odd angles is cored axially, and these three cores each meet one of the stepped cylindrical cores. Such a part requires an expensive die but the die yields a product which could not be duplicated in quantity at equal cost by any other means or with so little machine work and still hold dimensions within equally close limits.

In the smallest casting, Fig. 7, the two round tubes have cored blind holes and the threaded portion is cored at an odd angle for a depth about equal to the hole diameter. At the bottom of this hole a long slender hole is drilled to intersect the blind holes in the cross-tubes. This hole has to be drilled rather than cored primarily because it is not in or parallel to the

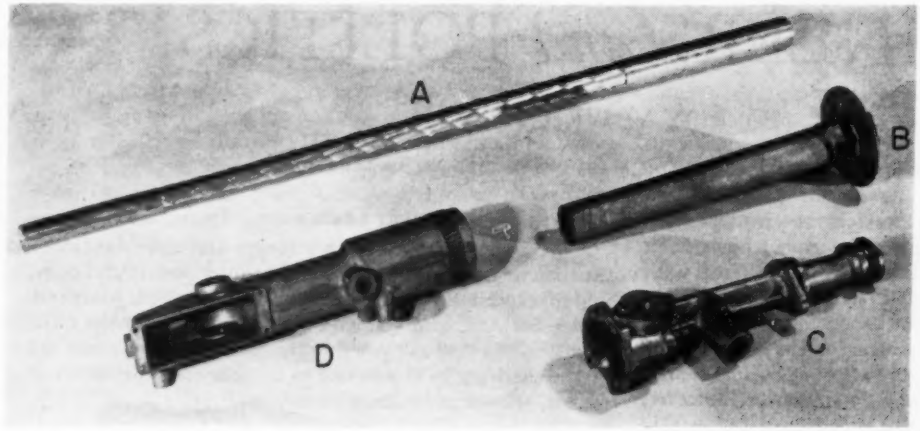


FIG. 8 FOUR UNUSUAL DIE CASTINGS

FIG. 9 THIRTY-FIVE CORES WERE USED IN THIS CASTING

axis of the cored hole in the threaded portion, and also because it crosses the hole in one cross-tube and is of the same diameter. Unfortunately, the drilled hole runs through a comparatively thick uncored section where porosity may occur and cause the drill to break or run out, but this trouble, if it occurs, may be difficult to avoid without a change in design. Had the axis of the threaded portion been such that a straight core of larger diameter than the cross-holes could have run down to the lower cross-tube, the chances of porosity would have been lessened.

The tapered tube A, Fig. 8, used as a lamp standard, necessitates the longest core yet employed in die casting. This core is 31 in. long and measures $^{11}/_{16}$ in. diam at its small end and $1^{1}/_{8}$ in. at its large end. Wall thickness of the casting is about $^{1}/_{16}$ in. Substantial taper of the core facilitates its withdrawal.

In the flanged agitator-post casting B, Fig. 8, a core 11 in. long is used. It tapers from $1^{9}/_{32}$ in. to about $1^{1}/_{16}$ in. diam where it meets a core coming from the opposite end that forms a step against which a bushing seats. Cores from each end and from three sides are employed in producing casting C, Fig. 8; the longest core is 9 in. and about $^{5}/_{8}$ in. mean diam. At the large end, a core of irregular shape approximating that of the external contour is used. Side cores are pins of nearly cylindrical shape some of which join the main cores. External slots, including one of irregular shape, are formed by die projections which may be classed as cores.

For casting D, Fig. 8, the main core is stepped and 7 in. long × 2 in. at maximum diameter. This core joins another which forms the rectangular recess at one end. Other cores produce holes in bosses and at corners of the oblong flange.

Castings such as that in Fig. 9 involve a multiplicity of cores, including one for each of the 21 oblong openings, three for coin slots, and a dozen for holes in bosses and fastening lugs. A slot running the length of the front face is formed by a corresponding projection or core in the cover die. It is often better, where oblong through-holes or slots are required, to have cores end at the back face rather than at the front face, as in this case, because the flash line, where cores end, may be less prominent or require less work in removal.

All three castings in Fig. 10 involve quite complex coring. Cores produce slots as well as interiors, and other holes and recesses. The largest casting is in magnesium alloy and axial cores from each end form the bore and holes between spokes. At the center is a bronze bushing placed over a central core and cast in place. All the side openings are produced by four slides each covering one quadrant. These move at such an angle that one slide can carry 12 short cores, each of which clears the side walls of the slots produced.

For the casting on the right in Fig. 10 a rather complex die is needed and it has a quite irregular parting. A core in the ejector portion of the die forms the interior of the dome. It has recesses which shape bosses, and an arclike rib joining three bosses. A side projection of the main core produces a boxlike recess at one side of the dome toward the external projection. For the latter, another core is needed as it must move at about a 45-deg angle to the axis of the main core to produce undercuts outside the dome but inside the projection arm. This angular core also forms a slot between bosses at the outer end of the arm. A small projection at the opposite side of the dome is made hollow by a core parallel to the axis.

Nearly the whole exterior of this casting is formed by the cover die but it has some short core pins and projections which form narrow slots that run clear through the dome wall for a part of their length but are blind for the remainder of their length, adding to the decorative effect. Two projections core out recesses for fastening screws.

Descriptions of core applications could be multiplied indefinitely, but the foregoing examples indicate their exceptional and varied utility in reducing the cost of die castings and making them perform their functions to best advantage.

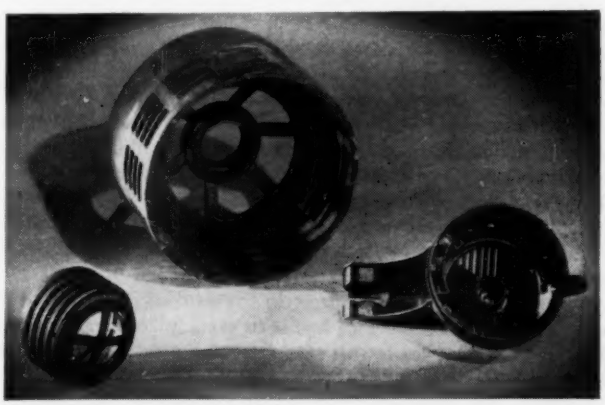


FIG. 10 COMPLEX CORING DESIGN

ENGINEERS *and* POLITICS

BY ROY V. WRIGHT

PAST-PRESIDENT AND HONORARY MEMBER, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONRAD N. LAUER, a Past-President of The American Society of Mechanical Engineers, when with the Link Belt Company in his early career, was associated with Frederick W. Taylor and his scientific-management activities. Later he was with Dodge & Day, and Day & Zimmerman, consulting engineers. He became president of the Philadelphia Gas Company and was active in several other business enterprises. Always throughout his long active career, however, he took a keen interest in civic affairs, participating actively in them. He believed so strongly in engineers doing likewise that he sought means to encourage them in this respect and, as one incentive, founded the Hoover Medal.

On a brilliant occasion, in the banquet room of the Hotel Mayflower in Washington, almost 18 years ago, April 8,1930, at the Fiftieth Anniversary Dinner of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Herbert Hoover, then President of the United States, was awarded the first of these medals for distinguished public service. The gathering included many eminent statesmen and engineers from this country and abroad. It was pointed out that the purpose of the medal was to commend the public service of engineers who go outside their strictly professional work to interest themselves in civic and humanitarian affairs.

"And," remarked President Hoover in accepting the medal, "the engineers have something to contribute to public service." Continuing, he said: "I need to cite but one direction of such contribution among a multitude.

"With the application of science to the development of our great national tools—our engines, our railways, our automobiles, our airplanes, our steamships, and a score of other great implements—together with the supplies of material upon which they depend, the engineer has added vastly to the problems of government, for government must see that the control of these tools and materials is not misused to limit liberty and freedom, that they advance and do not retard equality of opportunity among all our citizens.

"These great discoveries and inventions have brought great blessings to humanity, but they have multiplied the problems of government, and the complexity of these problems progresses with the increase of our population. Every county government, every municipal government, every state government, and the Federal Government itself, is engaged in constant attempt to solve a multitude of public relationships to these tools, which the engineers by their genius and industry constantly force to the very doorstep of government. And in solving these problems we have need for a large leavening of the engineering knowledge and engineering attitude of mind and engineering method. These problems of public relation are unsolvable without the technical knowledge of the engineer. They are unsolvable without the fundamental engineers' approach to truth. That is, first to determine the facts, arrange these facts in proper perspective, and then distill truth from them in the retort of experience."

Certainly the rate of progress in the field of invention, discovery, and applied science has been greatly accelerated since President Hoover made this statement in 1930, and today the need for wise and intelligent control is even more vital.

Address presented at a meeting of the Bloomfield (N. J.) Association of General Electric Engineers, East Orange, N. J., March 4, 1948.

WHY DEMOCRACIES FAIL

There is, however, an even stronger and more fundamental reason why every one of us should be interested in and be willing to expend time and energy to insure good government. Under our American system we proudly proclaim the citizens as rulers. Let me ask you frankly, however, how much training or coaching have you had as to your responsibilities as a citizen, or how to discharge them?

"Oh!" you exclaim, "things are all so complicated and I am so busy I can't afford to give much attention to such things. We elect representatives to attend to these matters."

All right. What do you or your neighbors know about these elected representatives? What part did you have in their selection? What are you doing to check up on their performance? Quite likely you will reply that after all you cannot exercise much control over such things, and you may even grouse a bit about the dishonest and self-seeking politicians who are sitting in the saddle. This lack of public interest is shockingly illustrated by the great percentage of our people who do not exercise their right of franchise, particularly at the primaries. Yet not only are the candidates selected at the primaries, but your party representatives are actually elected on that day and shortly thereafter assemble to select their party officers.

In this wonderful country of ours we seem to be sailing serenely along almost in a dream trance and in the belief that our Government is unassailable and a permanent institution, the continuance of which is something about which we need not concern ourselves. The fact is that serious students of government, who have analyzed the rise and fall of representative democracies, are deeply concerned over the direction in which we are drifting. It is a misfortune, indeed, that a good stiff course in "Why Democracies Fail" is not a requirement for active citizenship.

The late highly regarded author, Hendrik Willem Van Loon, tried to sound a note of warning in his syndicated series of articles in the daily press in 1940, on "The Story of Democracy." He hoped it would be published in book form, but the publishers were afraid to take the financial gamble on a subject in which our citizens were so little interested. May I commend to you the final paragraphs from Van Loon's series of articles:

"Elsewhere democracy has perished. It passed out through its own inherent weakness, a deliberate cult of mediocrity and absolute unwillingness to face unpleasant facts, an exaggerated devotion to material interests, an almost mythical belief in the efficacy of the spoken word, and the unwillingness of the leaders to have the courage of their own convictions.

"For, alas, none of the leaders seems as yet to have learned that democracy, being the most difficult and complicated form of government ever devised by human ingenuity, can be maintained only by constant watchfulness on the part of all of the citizens and by a most careful scrutiny and selection of those whom they wish to recognize as their leaders.

"Without that unselfish devotion to the interest of the community at large, all democracies are bound to end in dictatorship. That is the great lesson which the history of the last 3000 years teaches us beyond the vestige of a doubt."

I think I have said enough about the need for participation in government by every loyal and intelligent citizen. Let me remind you, first, that, in considering our part in it, we must

recognize that the party system is essential in a representative democracy. I am sure you would be greatly disturbed, in some places at least, if you looked into those who are taking an active interest in party organizations, and why they do so. Can we afford to leave it in their hands? You say you cannot give time to these things. But what will your business or other interests amount to if we develop into a dictatorship?

What can you, as an individual, do about it? That is the question we must face!

HOW TO GET STARTED IN CIVIC AFFAIRS

There are many ways of getting started in civic activities. This depends in part upon your own personality and ability, and the peculiar limitations under which you must function. It depends upon the community in which you live—upon the size of the town or city, its peculiar needs, and the effectiveness with which its affairs are being administered. This must be said, however, that room for substantial improvement will be found in any community, and that some of them are sadly in need of it. It must be said, also, that good leaders are often handicapped by lack of interest and support on the part of the citizens.

If you do not understand how party organizations are conducted, or how the community is governed, then you have some real studying to do. Personalities have such a large place and influence in politics and civic administration that you should learn something about those who have an influence in these activities. Obviously, it is not a difficult task to learn these facts in a small community. It is far more difficult in larger places, and yet if you begin down in the precinct—your own neighborhood—it will not be so difficult as you follow up to the ward level, and then to the city and county leaders. A large proportion of those who are active in the political organizations started as assistants of precinct committeemen and worked their way on up the line. It is not easy to break into the organization without doing some real spade work at the roots, and you may be subjected to some unpleasant experiences as you progress—but that is part of the game!

I well remember a senior student at the Newark College of Engineering who, inspired by its citizenship discussion course, wanted to be a precinct committeeman, to replace a man who was not greatly interested. The student went to the ward leader and expressed a desire to take on the assignment. The ward leader said O.K., the job was his. When the young man asked what steps he should take to get on the ticket, the leader replied that he would take care of the necessary details and the petition. It looked too easy and the student grew suspicious. He learned that he would be expected to support an undesirable leader and the deal was off. As a beginner, with no experience and with the primaries just ahead, he realized the futility of attempting to make a fight at that time. On the other hand, others have found conditions more agreeable and have become active in party affairs.

GET ACQUAINTED WITH YOUR REPRESENTATIVES

In some instances one can become acquainted with local politicians and men in office by attending political-club gatherings, but I have found it wise to qualify such advice. For instance, a young man desiring to become familiar with the local political situation and find some place where he might be helpful, visited a political club. He was disgusted and reported back that it was a beer-drinking group who reveled in shady stories and gambling, and that it was the last place in the world to find out anything about government, good or bad. On the other hand, there are political clubs where citizens gather to discuss seriously political problems, and where one can get a reasonably good line on the local political situation.

Incidentally, the women with their organizations are in many instances well ahead of the men in attemping to inform themselves in this respect. The League of Women Voters, a nonpartisan organization, is particularly active, its effectiveness in a community, however, depending upon how wisely its local leaders are selected.

There should be a strong taxpayers' association in every community; unfortunately, many communities do not have such groups, or they may be dominated by people too intent upon their own special interests, rather than that of the citizens as a whole. They might function more effectively if more of us took an active part in their activities. They do have a large and helpful influence on budget-making bodies, if rightly conducted.

VALUE OF PRESSURE GROUPS

Government touches intimately almost every one of our activities, and organizations of every sort have legislative committees whose duty it is to follow proposed legislation and keep their groups informed, or to suggest new legislation. Such groups, frequently designated as pressure groups, are invaluable. No legislator can be adequately informed about the great multitude of highly specialized problems upon which he must pass, and it is up to those of us who have the facts to see that they are made known to our representatives in the legislative bodies or in administrative positions.

As an individual you may want to pass facts directly on to your representatives. That is fine if you really give them facts or arguments based upon sound logic. Your representatives will appreciate this and be thankful for it. Unfortunately, most of those who write to their representatives, quite obviously, are not fully informed, or are so biased or emotionally inspired that the messages are not helpful and take time and energy from more important matters. Last year, as the State Senator from Essex County (New Jersey), for several days, during the height of the legislative session, I received an average of 150 pieces of mail and telegrams a day; only a very small percentage of these were helpful. You can make friends among your representatives, however, if you give them the right kind of dope.

In many of our communities, the governing bodies—town council or commission, or what not—meet in the evening. You can get a real line on these groups and meet public officers and civic-minded people by attending and possibly taking part in such meetings. Most of them have a place on the agenda for comments or statements from citizens.

There are many appointive offices in government, on boards, commissions, and the like, and those responsible for such appointments are on the lookout for promising candidates. Activity on your part in civic affairs may bring you into line for an appointment. In many instances such assignments may not require any time during your normal working hours. A number of engineers are holding positions of this sort in North Jersey communities. This is true of elective offices also; not so long ago an engineer served as the mayor of the City of Bloomfield.

These few comments are only by way of suggestion; according to your peculiar personality and abilities, the type of community in which you live and its needs, and your business and professional obligations, you can find plenty of opportunities for rendering public service if you really desire to do so. But first you must take time to size up the situation and then get busy in discovering ways in which you can make yourself most useful. I am sure you can find the time if you really want to do so, and certainly in light of the seriousness of the situation and what it means to you and yours in the long run, you cannot afford to sidestep your civic responsibilities.

BRIEFING THE RECORD

Abstracts and Comments Based on Current Periodicals and Events

Compiled and Edited by J. J. Jaklitsch, Jr.

MATERIAL for these pages is assembled from numerous sources and aims to cover a broad range of subject matter. While few quotation marks are used, passages that are directly quoted are obvious from the context and credit to original sources is given.

British Gas-Turbine Developments

THE application of the gas turbine by the United Kingdom to fields other than aircraft is discussed in a special article from British Information Services, by David Ferguson, British technical writer.

According to Mr. Ferguson, the main center for research on this new type of power plant is the National Gas Turbine Establishment at Whetstone, Leicestershire, and Pyestock, Hampshire, where all aspects of the gas turbine are studied. Subjects under investigation include the basic problems of air flow, combustion, behavior of materials at high temperature, compressor and turbine design, stresses in working components including vibration effects, and methods of manufacture. The manufacturing department makes experimental components of new design for test purposes and the results of these fundamental investigations are continually being passed on to industry for improvement. The Establishment also undertakes the technical assessment of new industrial designs and the testing of components and complete engines of the firms.

Recent developments include an improved axial-flow compressor and a combustion chamber having a pressure loss less than half that of previous designs; both of these developments are applicable to gas turbines in general.

The aim of the work is always first to obtain an understanding of fundamental principles by means of research work and then to apply this understanding to the design of components of the engines.

It is the policy of the United Kingdom Government to patent and exploit inventions of commerical importance made in its research establishments and to this end Power Jets (Research and Development) Limited, a wholly Government-owned company, is responsible for holding, and exploiting in the national interest, patents resulting from Government research and development in the gas-turbine field. The company possesses about 1700 British and foreign patents based on some 250 inventions covering the early work of Air Commodore Frank Whittle and his associates and later activities of Power Jets Limited and the National Gas Turbine Establishment.

The company has recently held two courses at a school at Lutterworth, Leicestershire, England, attended by representatives of about a dozen foreign countries, during which lectures were given on all aspects of gas-turbine technology, and representatives of British industrial concerns gave talks on special aspects of the problem. Similar courses are also given at the school for British engineers of the aircraft industry and from marine, railway, and power-station concerns.

Mr. Ferguson reports that in addition to the National Gas Turbine Establishment, research into marine applications of the gas turbine is carried out in an experimental station on Tyneside, in the north of England, under the Parsons and Marine Engineering Turbine Research and Development Association (PAMETRADA), which has been set up by a number of shipbuilding and marine-engineering firms engaged in the manufacture of turbine engines. The work is supported by the Department of Scientific and Industrial Research, and both firms and the Admiralty advise on the program to be carried out. The Association has equipment for the testing of both components and complete engines, and is actively engaged on the solution of various problems including that of transmission.

British Railways are alive to gas-turbine possibilities and last year the former Great Western Railway ordered from Metropolitan-Vickers a 2500-hp gas-turbine locomotive. It is expected that this engine will be on trial in the near future when running experience will be built up, and there is little doubt that the next few years will see a growing use of the gas turbine on the recently nationalized British railways.

A number of projects for marine purposes are being developed by British firms.

An experimental marine craft, said to be the first in the world powered by a propeller-driving gas turbine, was taken to sea by the Royal Navy in midsummer 1947 and preliminary trials have been completed satisfactorily. The gas turbine used was developed by Metropolitan-Vickers Electrical Company, Ltd., from the Beryl aircraft engine and has been installed in H. M. Motor Gun Boat 2009, a triple-screw craft built by Messrs. Camper and Nicholson. The engine drives the center shaft and takes the place of one of the normal complement of three 1250-hp reciprocating engines.

The basis of the engine is an aircraft jet-propulsion engine which consists of an axial-flow compressor supplying air to an annular combustion chamber where Diesel fuel is burned, followed by a two-stage turbine which drives the compressor. In this case the exhaust gases from the turbine, which normally constitute the jet, are further expanded through a four-stage turbine which is coupled to the propeller shaft through gearing. The exhaust from this turbine then escapes to the air through a funnel. The propeller shaft power output is about 2500 hp.

As a next step, Britain's Admiralty has ordered larger gas-turbine machinery from Rolls-Royce Limited, for installation in a vessel of the escort type, and a unit is also being built by the English Electric Company for a Royal Naval frigate.

Interest in the gas turbine for marine purposes is also shown by private companies. The Anglo-Saxon Petroleum Company intend to carry out gas-turbine experiments in the 8200-ton motor tanker "Auris" and to this end have ordered from the British Thomson-Houston Co., a 1200-hp gas turbine. The 1200-hp unit is to replace one of the four Diesel engines in the "Auris" for extensive seagoing trials.

In the field of electric generation, writes Mr. Ferguson, the Central Electricity Board have already ordered from Metropolitan-Vickers a 15,000-kw gas-turbine generator to be installed at the Trafford Power Station of the Stretford and District

Electricity Board. The plant should have an efficiency at least as high as, and probably higher than the most efficient steam-turbine plant in existence (26 per cent) and will probably be used for peak-load duties where the gas turbine shows to the best advantage by reason of its low capital cost, small volume, quick starting, and other favorable characteristics. A wide use of gas turbines can be envisaged in this field. In the generation of base-load power, the gas turbine should be able in future to offer considerably higher efficiency than the best steam plant, probably rising eventually to more than 30 per cent, but its use in this field will depend principally on its ability to burn cheap fuels such as boiler oil or pulverized coal. Experiments to this end are now proceeding

Densified Wood

DENSIFIED wood is a laminated material made from an assembly of resin-impregnated veneers that are highly compressed at the time of setting the resin. Depending upon the pressure used, the assembly will decrease during compression to approximately 50 per cent of its original thickness. It is said to be resistant to water, chemical attack, abrasion, scuffing, and temperature extremes, and it can be machined with modified woodworking equipment.

A booklet issued by the Bakelite Corporation, entitled "Densified Wood Made With Bakelite Resins," describes how this material is improving consumer products such as cutlery, household accessories, and sporting goods, and how it is being applied by industry for such uses as molds and dies, extrusion turntables, textile picker sticks, spool ends, and shuttles.

According to the booklet, the medium that successfully transforms porous water-absorbing wood into a hard water-resistant structure is Bakelite phenolic resin.

Almost any species of wood can be impregnated with this resin. The species, type of wood (heart, sap, spring, or summerwood), physical arrangement of the wood cells with relation to the surface (exposed end grain, etc.), and dimensions of the stock greatly affect the rate at which wood can be uniformly treated. Experience has shown that the most practical method of producing densified wood is by the use of impregnated veneers. The length of time required for impregnating thick sections of wood, and the uncertainty of the complete and uniform impregnation of heavy sections do not permit the wide application of Bakelite phenolic impregnating resin for large sections. Neither is it recommended to impregnate only the outer surface of thick sections of wood because subsequent changes in moisture content would cause severe checking and splitting of the outer treated part.

The rate of treating is also governed by the method of treatment. Two general methods of impregnation for compreg or densified wood can be used: spreading and total immersion.

In the spreading method, suitable only for thin veneers ($^1/_{16}$ in. or less), the undiluted resin is applied to the veneers as a surface coating on a conventional glue spreader and forced into the wood during subsequent compression. The wood may be conditioned to a desired moisture content before coating, or redried and conditioned following the coating operation. This latter is of a noncritical nature and may be accomplished very rapidly since the veneers are not swollen by the resin mixture, and most of the moisture which is removed is taken from the resin coating.

By the total immersion method, more widely used than spreading, wood veneers are totally immersed in a water solution of the resin diluted to approximately 30 per cent solids content. The immersion method of impregnation can be accomplished most simply by using an open tank and impregnating at atmospheric pressure. Although this method does not require expensive equipment, it is time-consuming. Impregnation time will vary from 24 hr for thin veneers ($^1/_{16}$ in. or less) to several weeks or longer for thick sections of lumber.

The time required for impregnating by the immersion method can be reduced considerably from 24 hr at atmospheric pressure to 2 to 3 hr by the use of an autoclave or pressure chamber. The conventional procedure employed when using an autoclave for impregnating is to first place the veneers or wood to be treated into the empty chamber. Air is then evacuated and the vacuum thus formed is maintained from 30 min to several hours, depending upon the cross section and volume of the wood to be treated. At the end of the vacuum period, diluted resin (30 to 35 per cent solids) is admitted to the chamber to completely cover the wood. Pressure should immediately be developed within the chamber (50 to 60 psi) by either air or hydraulic means, and maintained for from one to several hours. Upon removal from the treating chamber the wood is not completely impregnated. The resin is contained only within the wood cell cavities. If hardness and high density are the only requirements of the finished product, the wood or veneers can then be dried to a low volatile content and cured without further conditioning.

To achieve maximum dimension stability, the treated wood must undergo further conditioning before curing the resin. This conditioning allows for the complete diffusion of the resin into the cell walls. Thus it is necessary to maintain the high-moisture content acquired during treatment for from one to three days before any curing of the resin takes place. This can be accomplished simply by dead-piling the treated wood or veneers and covering them with a waterproof tarpaulin, or by dead-piling the treated stock in a room or chamber having high humidity (80 to 100 per cent) and normal room temperature.

After treating and conditioning, the veneers are ready for the compression process to produce densified wood. It is not necessary to coat the treated veneers with an adhesive.

Copies of the booklet are available upon request from the Bakelite Corporation, 300 Madison Ave., New York 17, N. Y.

Experimental Research Station

A $30,000,000 expansion of research facilities at the du Pont Company's Experimental Station, Wilmington, Del., has been announced by the company recently.

This major addition to scientific facilities will be an important factor in a program to increase du Pont's activities in fundamental, long-range research as well as research directed toward the development of new chemical products and processes.

Construction plans call for ten new laboratory and semiworks buildings for long-range research and development of new chemical discoveries. Existing laboratory buildings for nylon and other products will be enlarged. There are also to be thirteen new service buildings.

When expansion is completed, the company expects to have 900 technical employees engaged exclusively in research work at the station, of which about 200 will be transferred from other laboratory locations. Now there are approximately 500 at the station. The total of all employees there, technical and nontechnical, will approximate 2500.

Major part of the plan calls for construction of an entirely new section on 55 acres of the du Pont Country Club, which is adjacent to the station. The entire job, including work on new and existing buildings as well as outside work, is to be finished in approximately two and one-half years.

The chemical department, which is devoted exclusively to research, will use its new facilities primarily for fundamental research with the object of discovering new scientific facts without regard to immediate commercial use.

The engineering department, in its new facilities, will explore advanced engineering problems to develop basic data on manufacturing and control equipment and construction materials.

Many of the new facilities will be used by manufacturing departments for applied as well as long-range research. The applied research programs of the manufacturing departments will include further investigations of nylon, rayon, and other fibers and films, and the development of new materials in these categories; work aimed at major developments in pigments and related products; investigations for long-range developments of plastics; expansion of long-range research on new products and processes for agricultural and industrial chemicals; and development of products of high-pressure synthesis.

Jet-Propelled Helicopters

NEW facilities for the development of component parts for proposed U. S. Air Force jet-propelled helicopters have been established at the General Electric Company's Flight Test Center, Schenectady, N. Y.

The jet-helicopter development section was constructed at a cost of more than $100,000, not including special equipment loaned to the company for the project by the Air Force.

Evaluation, performance, and design of various types of power plants and aerodynamic testing of critical components will be included in the first phase of the project. The static testing of burners—various types of jet-propelled blade tips—will be a major portion in this phase.

The second phase of the long-range program will be the power-testing of the burners, which use kerosene fuel, in the outdoor test pit. Prototype jet engines to be used as helicopter power plants will be erected and tested in the pit to simulate ultimate operating conditions.

A 1000-hp electric motor will be used to drive the blade and to study drag when the jet-driven tip is not operating. While the burners operate under their own power the large motor will be used as a generator to measure thrust produced by the jets.

The first rotary-wing aircraft to employ a jet power plant is the McDonnell "Little Henry," 310-lb ramjet helicopter flight-tested in May, 1947. (See MECHANICAL ENGINEERING, January, 1948, pages 27 and 28.) Heavy engine parts, gear systems, and transmissions are eliminated, greatly reducing weight.

Rare Bibliographies

NUMERCUS rare and unpublished bibliographies on scientific and technical subjects are now available to industry as the result of the formation of a pool of unpublished bibliographies by the Special Libraries Association. The bibliographies in each case have been compiled by technical libraries affiliated with the Association, many of whom are outstanding literature searchers in their respective fields.

The phases of technology represented by the bibliographies are highly diversified. They include organic chemistry, agricultural chemistry, metallurgy, photography, physics, welding, mechanics, combustion technology, and others. Typical of the compilations available are bibliographies on ammonium nitrate, 1907–1947; portable prefabricated bridges, 1930–1944; centrifugal casting, 1910–1942; welding and fabrication of clad steels, 1907–1946; combustion studies in internal combustion engines, 1929–1945; and many other important and extensive compilations.

The pool is housed in the library of Battelle Memorial Institute, Columbus, Ohio, from which loans of the bibliographies are made. Anyone interested in obtaining the complete listing of the bibliographies should write Ralph H. Hopp, technical librarian of the Battelle Library, who serves as chairman of the SLA Bibliography Committee. His committee is also interested in the possible inclusion of other unpublished bibliographies in the pool.

Ore Research Laboratory

FLEXIBILITY of operations is the keynote of the new iron-ore research laboratory established in Duluth, Minn., by the Oliver Iron Mining Company. This latest addition to research facilities of the United States Steel Corporation will extend still further the studies of iron-ore beneficiation processes sponsored by Oliver for the past 55 years. Among other activities, the new laboratory will engage in long-range investigations into the development of commercially practical processes for the concentration of taconite—a compact, siliceous rock that must be ground to fine particle sizes before its iron oxide content can be effectively separated from the silica and minor gangue materials.

Because of the wide range of types of ore to be studied, the laboratory was laid out in such a manner as to permit rapid change-over from one type of ore-processing flow sheet to another. Relatively little equipment in the testing areas is fixed. Most of the equipment used is brought to the test areas when needed and when no longer needed removed to a storage area on the top floor of the laboratory building, where each piece of equipment has an assigned space. There it is stocked until required for future experiments.

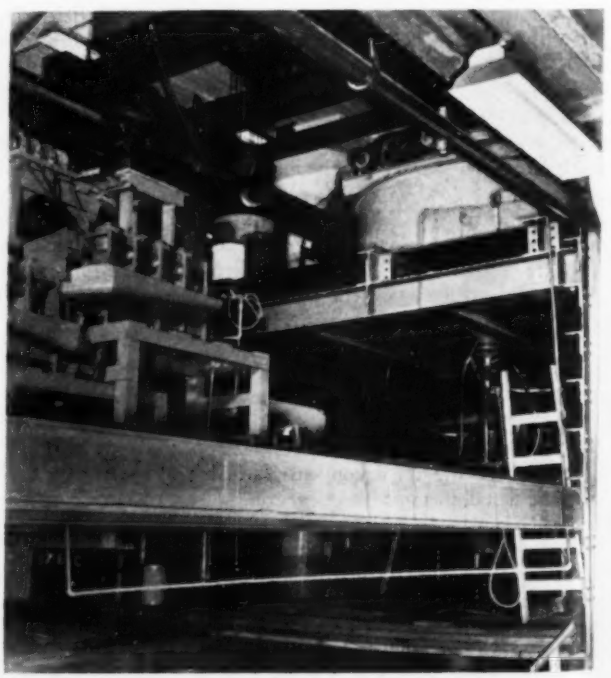


FIG. 1 ARRANGEMENT OF PILOT-PLANT SETUP IN NEW RESEARCH LABORATORY SHOWING POSITION OF LABORATORY EQUIPMENT FOR PURPOSE OF GATHERING INFORMATION ON REMOVAL OF IRON-ORE PARTICLES FROM LABORATORY SAMPLES OF CRUSHED ROCK

Two areas in the new laboratory have been reserved for setting up experimental ore-concentrating lines, popularly called "flow sheets" by the industry. One of these is the batch laboratory, where individual phases of ore-concentrating problems are studied, while the other is the pilot-plant area.

In the batch laboratory, tests of 1 to 1000 lb of representative material are conducted in bench-mounted units such as froth flotation cells, magnetic separators, and so on, while small pilot-plant operations, involving an output of perhaps 100 lb per hr, can be set up in the flow-sheet area. Equipment for grinding samples and determining their size fractions after grinding is located in this area to be used in conjunction with the foregoing tests.

The pilot-plant area handles tests on a larger scale. When it is desired to combine several phases of a problem developed in the batch laboratory, the necessary equipment is moved from storage and mounted in the pilot-plant area. This can be accomplished in the relatively short time of perhaps a few hours. Any type of flow sheet can be set up, although production is limited to about 1 ton per hr. Sometimes the purpose of the experiment is to test the flow sheet as a whole, while at other times the purpose may be to test individual pieces of equipment or a particular type of ore.

All working areas are piped for gas, compressed air, vacuum, and hot and cold water supply. Similarly, bus ducts that can be tapped anywhere make it possible to connect electrically operated machinery to 110, 220, or 400-volt power lines as required.

Chemical analyses of ore samples are necessary at various steps in the development of concentration processes. The chemical laboratory is equipped with every type of analytical apparatus and reagent for the highly specialized work carried out here, in addition to regular equipment for routine work of a more general nature.

The microscopic laboratory is equipped with microscopes of several designs all capable of being adapted to photomicrography, and a metallographic microscope of modern design. Complete facilities are available in a large darkroom for photographic processing.

Continuous Mining Machine

THE bituminous coal industry recently launched a $250,000 engineering program to design a machine that will mine coal cheaper and faster. The program's ultimate objective is a machine that will both cut coal "off the solid" without the use of explosives and load the coal continuously onto a conveyer or into mine cars.

Seventy of the nation's leading coal-producing companies, coal-land companies, and railroads have joined forces in supporting the project, it was announced by Bituminous Coal Research, Inc., the bituminous-coal industry's national research agency.

A selected Mining Development Committee will be guided by a two-year program that seeks first, to develop machinery and methods to produce coal at the face at the lowest possible cost, and second, to get such machinery into operation as fast as possible. It is contemplated that a basic design for a practical continuous mining machine which meets the major project requirements will be evolved in that time.

The industry knows that mine mechanization has not kept pace with rising wage levels and other costs of mining coal. The current project is another effort of the coal industry to provide a saving in cost of fuel to ultimate consumers. The industry is fighting to maintain coal's competitive balance of favor among fuels by more economical mining. The coal-producing companies are supplying the major financial backing of the project, supported by four coal-carrying railroads and ten coal-land companies.

Those concerned with the development desire a machine that will mine coal in seams of varying thicknesses and as low as 28 in. The exact type of machine, method of mining, and the size of coal to be produced will be evolved as the project progresses.

It is generally agreed that the effect of the machine will be to decrease coal-production costs by eliminating some and minimizing other mining operations as they are conducted today. The greatest savings in the mining cycle are to be made at the coal face. The machine would eliminate drilling and shooting, reduce movement of machines, and combine cutting and loading.

Savings on allied operations of timbering, track-laying, conveyer-moving, ventilation, and rock-dusting, would follow the reduction of working places in the mine. Such operations as transporting coal from the face to the main haulage and processing coal outside the mine will be greatly affected as well.

High Polymers

A NEW method for investigating the composition and properties of high polymers has been developed by the National Bureau of Standards in connection with a program for the study of the structure of natural and synthetic rubbers. The procedure consists in the pyrolysis, or thermal decomposition, of the polymer under high vacuum with subsequent separation of the products into gaseous, liquid, and semisolid fractions for analysis.

Polymeric substances—such as polystyrene, neoprene, rubber, nylon, lucite, and many others—owe their unusual strength, elasticity, and plasticity to the long chainlike structure of their molecules. Such compounds are formed in nature or in the laboratory by a process known as polymerization, in which sometimes as many as several million individual molecules (monomers) are joined by chemical reaction. Many polymers are made up of two different types of monomers and are known as copolymers. An example is GR-S synthetic rubber, which is formed by polymerization of a mixture of styrene and butadiene.

One of the most effective means for obtaining information on the structure of polymers and copolymers is thermal decomposition of a sample under conditions of molecular distillation in the absence of oxygen or other reactive substances. The term molecular distillation has been applied to that type of distillation where there is no return of escaping molecules to the evaporating surface. This is ordinarily accomplished by operating with high-boiling (low vapor pressure) liquids under such high vacuum that the mean free path of the escaping molecules is of the order of the distance between the surface of the evaporating liquid and the cooled condensing surface of the still. Under these conditions in pyrolysis, the fragments into which the polymeric chain is decomposed by heat may be distilled and collected without further fragmentation due to molecular collision. From a study of the way in which the polymeric chain breaks up—as shown by the length and type of fragments formed, the relative amounts of monomeric to longer fragments, and similar data—much can be learned about the arrangement of the monomeric units in the chain and the relative strength of the chemical bonds involved. Pyrolysis also provides a means for determining optimum conditions for recovery of the component monomers from scrap polymeric substances.

The apparatus, Fig. 2, developed at the Bureau consists essentially of a double-walled cylindrical flask similar to a

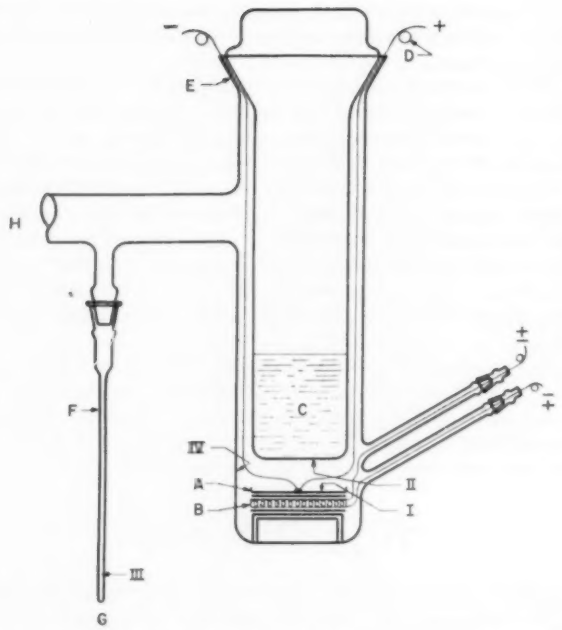


FIG. 2 DIAGRAMS OF APPARATUS FOR STUDYING THE STRUCTURE AND PROPERTIES OF HIGH POLYMERS

[(A) Tray, (B) platinum-wire helixes, (C) inner space, (D) platinum-rhodium thermocouple, (E) ground-glass joint, (F) sealing and breaking-off point, (G) Liquid-fraction receiver, (H) side arm.]

Dewar flask except that the inner vessel is joined to the outer jacket by a ground-glass joint. The space between the cylinders is evacuated to a pressure of one millionth of a millimeter of mercury and is connected, by means of a side arm, to receivers for the various fractions. At the bottom of this space is a small tray on which a thin layer (25 to 50 milligrams) of the polymer is heated to between 300 and 400 C by means of platinum-wire helixes encased in short lengths of glass tubing. During pyrolysis the outer wall of the flask is cooled by water flowing through spiral tubing surrounding the vessel.

Liquid air is first placed in the inner cylinder, and the temperature of the sample is then raised to the point of decomposition. All the products of pyrolysis, except those which do not condense at liquid-air temperature, then collect on the inner wall while the more volatile material is allowed to expand into a receiver. This gaseous fraction is analyzed in the mass spectrometer; its weight can then be calculated from volume, pressure, and composition.

To separate other fractions, the liquid air is removed from the central cylinder, and the temperature of this cylinder is raised in steps by the substitution of other refrigerants, such as dry ice, until room temperature is reached. This permits fractions which are volatile at temperatures between liquid-air and room temperature to distill over into liquid-fraction receivers, each of which is maintained at the temperature of liquid-air. The condensate on the inner wall, volatile at the temperature of pyrolysis but not at room temperature, is obtained as one fraction by dissolving it with benzene, collected in a platinum crucible, and vaporizing the benzene.

Additional fractions are provided by the semisolid residue in the tray and the deposit, nonvolatile at room temperature, which condenses on the outer wall of the evacuated space. This latter fraction, which may safely be assumed to have the same composition as the deposit on the liquid-air chamber, is not collected, but its weight is calculated by subtraction of the weights of the other fractions from that of the sample. The gaseous and liquid fractions thus obtained are analyzed in the mass spectrometer, while the semisolid fractions are identified by other physical and chemical methods of analysis.

Because of its relatively simple structure, polystyrene was the first polymer selected for study. This compound was found to break up at the temperature of pyrolysis into the monomer, dimer, trimer, and some tetramer. The most striking observation was the consistency with which only small fragments, none longer than the tetramer, were obtained. Doubtless the larger molecular fragments became entangled in the mass of long-chain polystyrene molecules and were held until they decomposed further into shorter lengths.

The program now under way at the Bureau includes fragmentation studies of polybutadiene, polyisoprene, natural and synthetic rubbers, nylon, and "popcorn" polystyrene. Efforts will be made to develop techniques that will provide longer-chain fragments for analysis. Plans are also in progress for carrying out similar experiments on a much larger scale with samples of several hundred grams. This will permit the collection of fractions of a size more convenient for chemical analysis and physical tests.

Reports From Germany

Mechanical Engineering

A NUMBER of significant German advances in mechanical engineering are contained in five reports now on sale by the Office of Technical Services, Washington 25, D. C.

The reports are based on visits to machine manufacturing and using plants, and describe and illustrate design and production of pumps, compressors, rock drills, vibrating ball mills, conveying machinery, and allied products.

Report PB-40314 presents information on employment, production, material specifications, heat-treatment, and shop practices in the pump, compressor, and rock-drill industries. In contrast with American practice of materials engineering in this field, German manufacturers of rock-drilling equipment follow a set formula in ordering and handling their materials, the report points out. The system is personalized and semi-secret. Engineers use metal handbooks and order by brand name or leave the responsibility for selecting the proper material to the suppliers' metallurgists.

The high cost of materials compared with the cost of labor is probably responsible for the German habit of paying more attention to design than to metal specifications, according to the report.

Materials engineering in Germany, it is reported, is kept within the province of top technical workers. Subordinates are supposed to do what they have been told without knowing the why or wherefore. As a result of this manifestation of German philosophy in industry, most operations are routine in so far as metallurgy is concerned. No attempt is made to have the workman technically understand the peculiarities of the materials he uses.

Report PB-40283 describes a German ball mill of novel design, capable of rapid extra-fine grinding. The novel feature of the mill is the peculiar motion which the vibration of its cylindrical shell imparts to the steel or porcelain-pulverizing balls. Laboratory-size mills of this type have been purchased and used in the United States but industrial sizes have not been used, according to the report. It appears to be standard equipment in Germany for pulverizing a variety of materials including tungsten carbide, metallurgical powders, cosmetic

talc, paint pigments, graphite, pharmaceuticals, and food products.

Report PB-32583 contains information on engineering, design, and manufacturing of conveying machinery, gear reducers, roller and silent chain, other types of steel and malleable chains, and coal-preparation machinery. Forty-four German plants were visited. Among the drawings are several showing various coil-spring idlers, idler rolls, crusher rolls, and chain used in underground coal-mine conveyers.

Report PB-49218 contains information on the technical and economic status of the German chain industry. Production processes are summarized in the following groups: cycle chain; small and medium-pitch roller chains; heavy roller chains; and rough bush chains, conveyer, and elevator chains. Production operations of the 17 plants visited are presented under the following headings: materials; grinding; sizing; heat-treatment; riveting; pressing operations; and inspection.

Report PB-369 on the German mechanical-engineering industry includes information on high-pressure steam generators at power stations, including description and performance of a Benson boiler at a Leipzig power station. Hammer mills for pulverizing coal and retort stokers for steam generators as manufactured by Frankel and Viebahn, Leipzig, are described.

Portable aerial ropeways, conveyers, and a novel type of rotary excavator made by Bleichert-Transportanlagen G.m.b. H. of Leipzig, are described. Photographs and drawings of the rotary excavator, known by the name of "Kugelschaufler," are included in the report. The machine, intended for moderately light duties just below the range of standard $^3/_8$ or $^1/_2$-yard excavators, is built on the dredger principle. The makers claim that all the advantages of the principle are obtained, i.e., low power consumption and light maintenance costs. Briefly, the head consists of a number of shovels which rotate at the end of a steel tube of large diameter. These shovels pick up the material and transfer it to a conveyer inside the tube which discharges the material on another swinging conveyer of adjustable height for either loading on dumpers or piling where required.

Another section of the report describes crushing, grinding, the screening machinery manufactured by the Krupp works at Magdeburg. Information gathered at this firm includes details of a crushing and screening plant for rubble and a novel machine for grading coal. The machine separates the fines from the coal and consists of a table containing a number of revolving eccentric disks through which the fines fall. The coal to be graded is delivered to the table by a conveyer and the revolving disks carry the coal forward the whole length of the table. The fines up to 12 mm fall through the first section and the fines up to 20 mm through the second section, all coal over 20 mm being discharged over the end of the table. More than 200 tons of coal per hour can be separated on this machine.

Staple-Fiber Machinery

A comprehensive report PBL-85168 on recent improvements in German staple-fiber processing machinery, many of them of interest to American industry, is on sale by the Office of Technical Services, Washington 25, D. C.

Spinning machines, cutters, aftertreatment machines, openers, driers, and baling presses are described in the first part of the report. Among developments of interest is the Grusschwitz or "Gru-Gru" cutter which is used with practically no complaints in nearly all German plants. The positiveness with which the tow is held and fed at the point of cutting and the simplicity of parts exposed to acid has won for the cutter almost unanimous approval, according to the report. No water is fed with the tow. The only complaints against the machine concern problems connected with the rubber-covered steel wheels and their tendency to chip and deteriorate. Different sets of wheels are used for cutting different fiber lengths.

Another development, cited as of special interest by the report, is a three-stage-type baling press with a capacity of 20 tons per 24-hr day. The press operates in three distinct stages: (1) Loading and prepressing of staple fiber; (2) pressing; and (3) unloading of the bale. The three stages or housings are equally spaced 120 deg apart, and mounted on a turntable which can be turned from position one to position two, an empty housing from position three arrives at position one, while another housing with the completely pressed bale is placed in position for unloading.

The second portion of the report discusses raw-material and utility requirements for manufacturing staple fiber. Practically all German firms were conscious of their total water consumption and the need for reducing it, but on the whole, the expansion of the German staple-fiber industry has not included well-worked-out water systems. At one modern plant at Lenzing (Austria) water consumption is about 400 liters per kilogram of finished staple. At an older plant at Kelsterbach, it is 1000 liters. Steam and power, conditioning, ventilation, refrigeration, caustic soda, carbon bisulphide, and the spin bath are also discussed.

Part three of the report describes carbon-bisulphide recovery equipment and methods in considerable detail. All German plants practice carbon-bisulphide recovery and probably 30 per cent recovery is achieved in most cases, according to the report. Two basic types of collecting systems are used involving recovery from the tow or recovery from the cut flakes. The actual recovery takes place either by condensation of the water and carbon-bisulphide-vapor mixture or by activated-carbon absorption. Some of the latest systems being installed point the way to the recovery of virtually all free carbon bisulphide in the fiber at the point of recovery, the report states.

A fourth part describes the continuous Lurgi vacuum crystallizers installed by the firm, Spinfaser A.G., at Kassel-Bettenhausen to recover 120 tons of Glauber salt from the spin bath daily. The three German firms using these crystallizers were well satisfied with them. Complaints centered around defective linings, especially in the rubber-lined type, and the fact that the machines were not easily operated at reduced output.

Tungsten-Carbide Research

A test to predict the resistance to tool wear of any specimen of hard metal was developed by the Germans according to a report (PB-79296) on tungsten-carbide research on sale by the Office of Technical Services, Washington 25, D. C.

The report gives a general survey of the research program of the Osram laboratory during the war years and discusses the latest theories on the fundamental metallurgy of hard metal as developed by Dr. Walter Dawihl. It describes his experiments to relate the practical performance of hard metal with metallurgy, and discusses the effect of crystal formation and shape on physical properties.

In view of the fact that grinding plays a major part in the production of hard metal tools which will function satisfactorily, exhaustive researches were carried out on the manufacture, testing, and use of grinding wheels. Comprehensive investigations were made on the manufacture of "diamond" draw dies and the properties of dies were compared carefully with those of hard-metal dies. The grinding of hard-metal tools with diamond grinding wheels was studied and led to a long program of research in collaboration with the grinding-wheel industry with the result that Osram's research depart-

ment eventually took over the direction and integration of research for the whole industry.

The report contains a description of a technique of coating steel with a thin hard metal skin. Composition of the metal is given. Descriptions of the processes of making boron carbide and titanium boride are included, together with a brief summary of the work done on sintered iron and steel.

Spindle Dynamics

A survey of some of the theoretical concepts relating to textile spindle dynamics is contained in a report (PB-86030) on sale by the Office of Technical Services, Washington 25, D. C. The survey was designed to help clarify and evaluate spindle problems.

The entire spindle problem, according to the report, would be very simple, or would not exist at all, if there were no irregularities in the yarn load, but such irregularities always exist. The dynamic properties of spindles are therefore surveyed with reference to the existence of load irregularities in rotating masses.

The problem of relating spindle dynamics to spindle design in order to meet all the spinner's requirements is not simple, the article points out in a discussion of practical considerations. The spinner gives preference to the most quiet-running spindle, drawing no great distinction as to whether irregularities result from vibration or from gyroscopic motion of the spindle shaft. Since unwanted motions are a nuisance, causing the spinner to fear yarn breakage, uneven yarn, and other defects, practical demands give rise to contradictory requirements. The rotating mass should have the greatest possible ease of adjustment, but the requisite allowances for play are then a source of trouble in practical operation. In addition, the spindle shaft, which must not be particularly thick, may be subjected to severe stresses if the bobbin is doffed carelessly. Furthermore, bearings must be reliable and possess the longest possible service life.

The following properties and concepts of spindle dynamics are discussed in detail: Rotation around a free axis, rigidly mounted materials axles, vibration, critical speed, rigid spindles, flexible spindles, gyroscopic motion, spindles as gyroscopes, stresses, and spindle motion and damping oscillations. Experiments are cited to illustrate many of the properties.

Military Bridges

German counterparts to the well-known military "Bailey bridge" used by the U. S. Army are described in a comprehensive report (PB-85186) on German military bridges now on sale by the Office of Technical Services, Washington 25, D. C.

The German "J-type" bridge is a girder bridge which can be adapted as a simple stringer bridge, floating bridge, trestle bridge, ferry bridge, or can be utilized for rafts, landing stages, or approaches, the report states. The J-type bridge varies considerably in design details from American military bridges.

The pontons are made of four parts: Two end sections and two intermediate sections. Ponton distance pieces are used to connect the end sections of adjacent pontons.

The joints between stringers or girders are not staggered, but are made continuous by use of a relatively heavy girder connector. The connector enables the builder to have clear spans of 5, 10, 15, and 20-meter lengths.

Rafts or raft sections are joined together by a raft connection on top of the side rail. There is no difficulty in joining sections.

The use of rollers (as with the Bailey bridge) is combined with the hand method, similar to American practice, of erecting trestles from shore or from completed trestle bays. The method is excellent for heavy trestle erection, the report states. A launching nose and a launching lever are included in the equipment as tools but not as construction parts.

The transoms used are not complete and ready for insertion of trestle legs but require the addition of attachment plates. The same plates may be used for fastening additional transom sections to permit construction of a wider bridge. A well-designed abutment still is used.

Infrared Heating

PRACTICAL considerations relating to the industrial application of infrared heating were discussed by Paul H. Goodell, Trumbull Electric Manufacturing Company, Norwood, Ohio, at the 1946 ASME Annual Meeting.

Mr. Goodell pointed out that heating cycles, formerly considered to be of short duration, can be even further reduced through proper consideration of five "quality factors" essential to the successful application of radiant energy heating.

Uniformity of heat applications, the first quality factor, is too often assumed in industrial heating practice, either because long-time cycle convection processes have not required a precise consideration of the uniformity of heat transfer or because the use of thermostatic control provided average results of sufficient accuracy. Temperature measurements may serve as an adequate guide in establishing heat-transfer rates under stabilized conditions and with products having uniform properties. As customarily applied on a production scale, they may control average or ultimate temperatures, but there can be no assurance that several products, or even all parts of the same product, will attain a desired temperature at the same time, particularly when air temperature is relied upon as the controlling medium.

In convection ovens this time gradient in attaining temperature is influenced extensively by the velocity of the air in contact with the product surfaces. With infrared heating it is directly proportional to the concentration of energy intercepted by the product surfaces, all other factors being equal. Uniformity of heat transfer accordingly depends upon the energy-distribution characteristics of the lamp bank and the relative location of the product surfaces with respect to the lamp bank. Since infrared heating is usually employed for short-time cycle processes, as compared with convection, the uniformity of heat application becomes much more critical and therefore of primary importance in the application of lamp equipment to thermal processes.

Investigation shows that more than 80 per cent of the demand for infrared heating service centers around the self-contained reflector-type lamp commonly designated R-40.

While lamps are often used for localized heating over small or confined areas, where they are most effective, the more predominant use is in large banks, tunnels, or ovens for the organized handling of production processes. Here use is seldom confined to a single plane or a single lamp.

The curves shown in solid lines on Fig. 3 graphically show the maximum energy available at various distances and in various planes from a single bank of lamps which might otherwise form one of the principal heating surfaces in a typical oven. For purposes of clarification, the average heat concentration of the plane parallel to the lamp bank and at a distance from the lamp filaments equal to $1^1/_2$ times the average spacing between lamps is represented as the unity or 100 per cent value.

The second quality factor is the application of the proper amount of energy at the most advantageous time in the cycle.

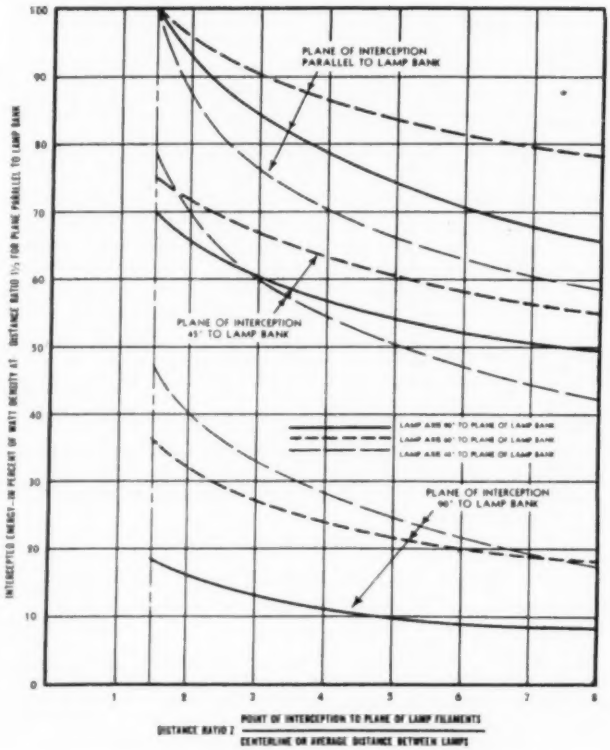

PLANE OF INTERCEPTION PARALLEL TO LAMP BANK
PLANE OF INTERCEPTION 45° TO LAMP BANK
PLANE OF INTERCEPTION 90° TO LAMP BANK
INTERCEPTED ENERGY—IN PERCENT OF WATT DENSITY AT DISTANCE RATIO 1½ FOR PLANE PARALLEL TO LAMP BANK
DISTANCE RATIO 2 POINT OF INTERCEPTION TO PLANE OF LAMP FILAMENTS / CENTERLINE OR AVERAGE DISTANCE BETWEEN LAMPS

FIG. 3 ENERGY-DISTRIBUTION CHARACTERISTICS FOR LARGE BANKS OF R-40 INFRARED LAMPS

Observations indicate that faster heating through higher concentrations of energy early in the cycle might result in complete curing of the material in possibly three minutes at a maximum temperature of 375 F. With uniform application, radiation can often be applied in such concentration as to produce high skin temperatures for curing surface coatings, with a minimum of heat loss through the cross section of a product. Skin heating in this manner may reduce the total energy consumption on some applications to a point that will preclude the consideration of other methods of heating regardless of potential fuel-cost advantages. The after-cooling problem is also diminished with skin heating.

Casehardening can often be avoided in water evaporation processes by following the technique used in skin heating. High concentrations of energy early in the cycle will provide necessary heat of evaporation through the mass of a product while the water is still present to serve as the heat-conducting medium. When this procedure is not followed, products having low thermal conductivity may caseharden, greatly reducing the effectiveness of subsequent heating.

Another advantage resulting from the directional control of infrared is the possibility of tailoring the quantity or rate of heat transfer in a portion of the oven cross section to compensate for large mass variations in some types of products, thus avoiding excessive temperature gradients that might result with other methods of heating.

The third quality factor relates to the proper exposure of product surfaces both from the standpoint of producing effective heating results and judiciously employing the energy provided. Since infrared energy is converted to sensible heat at the product surface or point of interception (excepting for materials transparent to infrared energy), it is commonly referred to as surface heating. This also holds true for surface coatings where pigments opaque to infrared energy are employed.

Materials having high thermal conductivity usually require exposure only on one side of principal surfaces. Materials of low thermal conductivity should be exposed from both sides if the temperature gradient through the cross section is to be held to a minimum. Materials that are transparent or act as reflectors to infrared energy should preferably be processed by other methods of heating.

Space utilization in infrared ovens will appreciably influence both performance and operating economy. Surfaces should not be allowed to eclipse each other for reasons of providing uniform heat application. On the other hand, poor space utilization by the products to be heated may result in reduced conversion of the radiant energy to sensible heat with an associated drop in efficiency. Where alternate methods of material handling are available, wide slow-speed streams of work usually result in more efficient oven design and are to be preferred to narrow and correspondingly higher-speed operations which invariably require greater space.

Like many other types of electrical equipment, infrared ovens should be operated at near maximum heating load as possible (with any given electrical demand) for lowest-cost performance.

The fourth quality factor relates to uniformity of product and the necessity of providing means for varying the amount of exposure if the product or method of material handling compel latitude in the amount of exposure. This often occurs in evaporation processes where granular, fiberous, or leafy products are to be handled. Granular products may be turned mechanically during processing. Other products may require gravity separation during processing so that fully processed parts are removed from the heating zone while other parts are allowed to remain for prolonged heating. The material-handling or ventilation system or both must necessarily be suitably adapted to the intended process to accomplish these results.

The drying of metal products following surface preparation or cleaning is a typical case where product control may require special attention. In this case, water free to puddle can usually be held in a thin over-all film easily dried by radiation if a

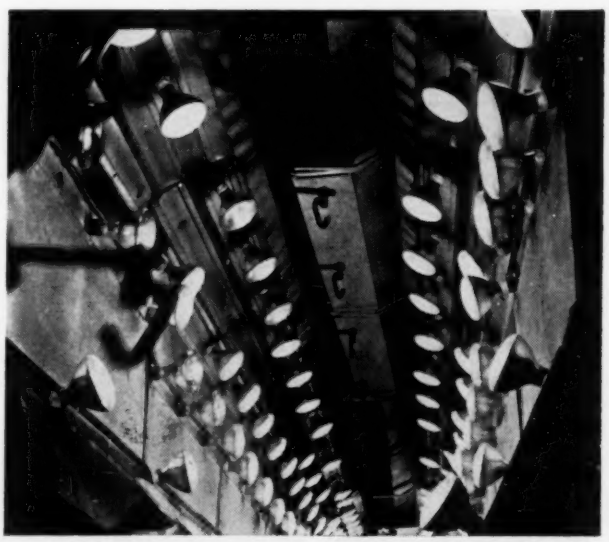


FIG. 4 MODERN 55-KW OVEN COMBINING INFRARED AND CONVECTION HEAT FOR BAKING A REPRESENTATIVE SYNTHETIC ENAMEL FINISH ON SHEET-METAL PRODUCTS

suitable wetting agent has been employed in the final solution. Otherwise, drying with infrared is virtually impossible as thickness of water films is a vital factor in radiation drying. It is therefore evident that products must present a uniform heating objective or the process must be controlled in a manner suited to the required variations.

Atmosphere control is the fifth quality factor. If the atmosphere in contact with the product does not approach the desired service temperature or the velocities are excessive, the results will be counter to the heating objective. If the velocities are not adequate to effectively remove vapors as produced during the curing of most synthetic coatings, loss of gloss and porosity may result with a sacrifice in the desired protection, appearance, and durability qualities.

Relatively high velocities may be very helpful during the final stages of water evaporation processes. Except for such processes temperature stability is almost directly dependent on the atmospheric conditions immediately surrounding the products. It is therefore evident that some convection is an essential requisite of most if not all infrared heating applications. Fortunately lamps produce both convection and radiation, but until recently few installations took advantage of this fact.

Simple enclosures were first used to preclude external drafts, but simultaneously much of the by-product convection was retained with stratification tendencies, as provisions for air-recirculation had not been adopted. It quickly became evident that a significant portion of the heat energy was being converted to convection and as service temperatures have increased to provide shorter time cycles, so have convection temperatures increased depending on the insulation qualities of the enclosure.

Since many lamp ovens are of the continuous type, steps should be taken to avoid excessive heat losses at the work entrance and exit openings. Air locks, traps, or air curtains (the latter discharging a high-velocity curtain of air across the openings), should be used to conserve the convection heat and at the same time prevent the escape of fumes which may be of a toxic nature if derived from urea-formaldehyde finishes or other synthetic products. The escape of radiant energy through the work entrance and exit openings may be prevented, first, by the effective loading of the oven to assure maximum conversion of radiation to sensible heat; second, by directing lamps away from the entrance and exit openings; third, by the use of supplemental baffles or if desirable by the addition of light locks, frequently built around a 180-deg turn in the conveyer system at each end of the oven.

Although infrared heating provides a wide range of use, each application should be analyzed as to adaptability and proper equipment design.

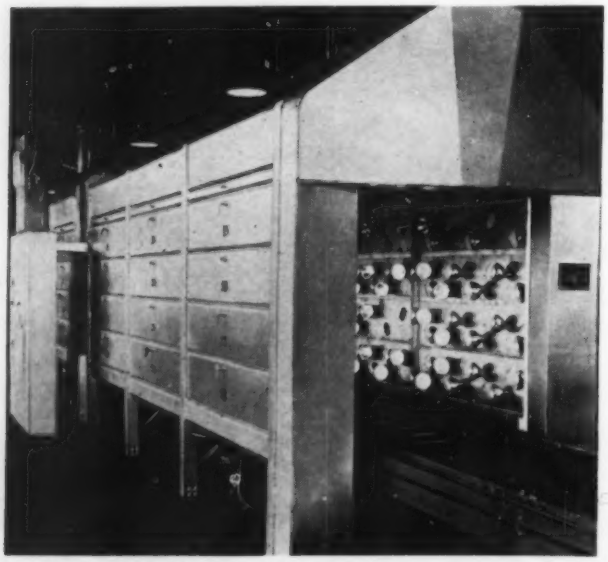


FIG. 5 INFRARED OVEN WITH PALLET CONVEYER INSTALLATION FOR HANDLING HEAVY PRODUCTS

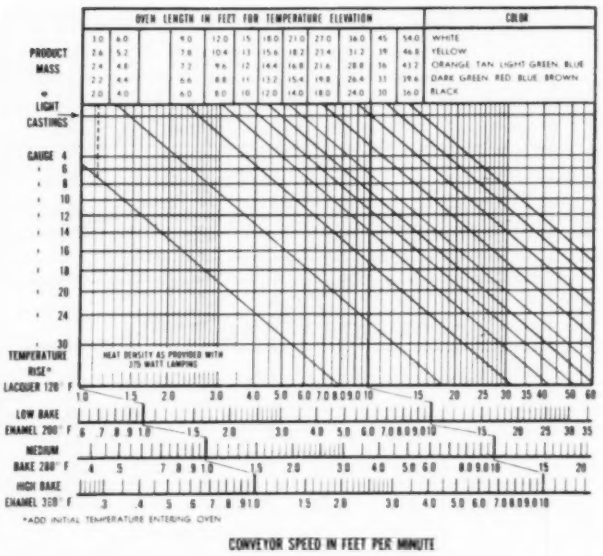


FIG. 6 CHART FOR COMPUTING OVEN LENGTH FOR THE HEATING OF STEEL PRODUCTS USING AN ENERGY CONCENTRATION OF 7 WATTS PER SQ IN.

(To use chart, select intended speed of handling on scale providing desired temperature rise. Follow vertically from this point to intersection of horizontal line adjacent to product mass. From this point follow nearest diagonal line to table where the length of required heating zone will be found opposite color of product.)

Electrical Analyzer

A CALCULATING machine, called the Anacom, based on a new approach to mathematics and designed to solve difficult problems in the fields of electric circuits, machinery, applied mechanics, hydraulics, and heat flow, is reported to have been built by Westinghouse Electric Corporation and installed in a new laboratory at East Pittsburgh, Pa.

Instead of solving equations according to the rules of formal mathematics, the essential elements of the machine to be analyzed are synthesized from an array of electrical devices such as capacitors, resistors, and inductance coils. This electric analog of the actual machine behaves electrically exactly the same as the real machine does mechanically. Forces applied to the real machine, like short circuits, impacts, application of heat, or whatever constitutes the actual problem, are represented by electric voltages or currents that can be applied to the synthetic machine setup on the computer at the same places where the actual forces occur. The resulting voltages representing stress, motions, temperatures, and the like, can be measured accurately at any point by merely connecting the leads of a cathode-ray oscilloscope to the analogous parts of the synthetic machine. A trace on the oscilloscope screen is an exact replica of the magnitude and wave shape of the corresponding quantity in the actual machine.

The process is similar to building scale-model replicas of dams, airplane structures, and ships so they can be stressed with all forces that the full-sized object must resist to prove a design. Only the synthetic analogs built up on the Anacom are said to be far more flexible than scale models. Any individual part of the electric analog can be checked exactly as it reacts to the applied forces. The forces themselves can be as complex as desired and can be repeated over and over again. Even forces that would cause destruction to an actual machine or its scale model cause no damage to the synthetic electric analog and can be repeated with infinite variations for complete determination of the performance of the actual machine.

Bessel Functions Tables

OF interest to nuclear technologists, as well as other design engineers and physicists, is the recent publication of extensive tables of the Bessel functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$, and $K_1(x)$ in the region 0 and 1. These tables, prepared by the National Bureau of Standards, are now available as a 71-page booklet, constituting the first in the new Applied Mathematics Series, which will include mathematical tables, manuals, and studies by the National Applied Mathematics Laboratories of the Bureau.

Because of the frequent need for numerical values of the Bessel functions in many physics and engineering problems, the tables have been computed at much closer intervals than previous tabulations of these functions, thus enabling the user to obtain almost the full accuracy of the table, over most of the range, by linear interpolation. Specifically, the tables give the values of $Y_0(x)$ and $Y_1(x)$ with first and second differences for $x = 0(0.0001)0.05(0.001)1$ and the values of $K_0(x)$ and $K_1(x)$ with first and second differences for $x = 0(0.0001)0.03(0.001)1$. To simplify interpolation in the table of $Y_0(x)$ and $Y_1(x)$ in the small region between 0 and 0.0050, auxiliary functions have been tabulated at an interval of 0.0001. Similarly, auxiliary functions related to $K_0(x)$ and $K_1(x)$ have been tabulated for $x = 0(.001)0.030$.

Applied Mathematics Series 1, Tables of the Bessel Functions $Y_0(x)$, $Y_1(x)$, $K_0(x)$ $K_1(x)$ $0 \leq x \leq 1$, may be obtained only from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 35 cents per copy.

Superheater Tube Failures

THE results of an investigation to determine the cause of failure of an abnormal number of end superheater tubes, were reported by H. B. Snider, general foreman, utilities division, and F. H. Ward, chemical engineer, Humble Oil and Refining Company, Baytown, Texas, at the 1948 ASME Spring Meeting.

Continued failures of end superheater tubes in a 275,000-lb per hr, 650-psi boiler were causing unscheduled shutdowns and interrupted service. Research and test work was begun to determine the cause of these failures and to take the necessary corrective steps to eliminate them. Close examination of the ruptured tubes indicated that the cause was excessive deposits in the tubes. The normal causes for carry-over such as excess boiler-water alkalinity, high total solids, and high water level were checked and discarded since no evidence was found that showed any of these conditions abnormal. It was then decided to make extensive tests of the steam produced in the drum and of that fed to the superheater tubes from the saturated superheater header. Sampling connections were installed in the drum, twelve of the connector tubes between the drum and saturated header, the saturated superheater header, the saturated header drain, and the eight end superheater tubes. Standard sampling apparatus was set up and uniform readings were obtained before any data were recorded.

The saturated header is built so that the width of space in which steam enters the header through the connector tubes is less than the width of the space in which steam leaves the saturated header through the superheater tubes. This construction causes lateral flow of steam at the ends of the saturated header in order for the end superheater tubes to be furnished with steam from the connector tubes. The high velocity of steam making a 90-deg turn precipitates solids to the end of the saturated header where a concentration occurs. The end superheater tube obtains steam from this section of the header, and therefore overheating of this tube occurs.

The quality of steam produced in the drum was 0.60 ppm total solids average, while that being fed to the saturated superheater header was essentially the same. Since superheater tube failures due to carry-over are not generally expected with steam quality less than 1 ppm total solids, it was felt that the steam produced in the drum and fed to the saturated superheater header was satisfactory and that the cause of tube failures was not due to steam of poor quality from the boiler drum.

The quality of steam in the saturated header was 1.4 ppm; at the saturated header drain it was 13.35 ppm total solids. It was evident from the data that a solids concentration was occurring in the end of the saturated superheater header.

Further proof of this concentration of solids in the end of the saturated superheater header was noted when a sample of steam obtained from the end superheater tube contained 3.15 ppm total solids while samples of steam from the adjacent superheater tubes contained considerably less total solids. Data showed that the concentration of solids which occurred in the saturated superheater header was being fed to the end superheater tube.

It was decided to install an additional connector tube between the saturated header and the drum on each end of the boiler at a point just opposite the superheater tube next to the end superheater tube.

It was also decided to replace the old drum internals with new internals of the same design. It was suspected that the old internals might have been leaking because they had been removed and replaced a large number of times during the test work.

The boiler was returned to service and data obtained showed a decided improvement in the quality of steam in the drum (0.30 ppm) and saturated superheater header (0.30 ppm average). The improvement was said to be due to the influence of the new drum internals which are more effective in reducing the entrainment in the steam from the drum. An improvement in the values at the drain (0.66 ppm) and at the superheater tube sampling points (1.0 ppm) was also noted. This was reported to be due to the additional connector tubes which cause more equal steam distribution within the saturated header and to the superheater tubes from the header.

To prove the value of the additional connector tubes in reducing solids in the end superheater tubes the boiler was removed from service and these tubes were fitted with a 3-in. plug having a $^3/_{16}$-in. drain hole. The boiler was then returned to service and samples of steam were taken from the saturated superheater header drain and the end superheater tube. They showed 5.5 and 1.43 ppm total solids, respectively, which, when compared with 0.66 and 1.00 ppm, obtained after installation of new internals and connector tubes, showed an improvement of 4.84 ppm at the drain and 0.43 ppm at the end superheater tube.

During the investigation, data obtained indicated solids in

excess of 1 ppm in the steam withdrawn from the saturated header through a $^3/_4$-in. multiple-hole sampling nozzle which contained twenty $^1/_8$-in. holes drilled on 6-in. centers in a spiral to form $2^1/_2$ complete turns in 9 ft 6 in. Simultaneously, samples of steam withdrawn from the drum through a single-hole sampling nozzle indicated total solids in the steam to be less than 1 ppm. As this variation was unreasonable and could not possibly exist, it was suspected that one of the sampling nozzles was in error. With this in mind, data were obtained which proved that the multiple-hole sampling nozzle was in error and that the other sampling nozzle in the boiler drum was reliable.

The total solids in the steam entering the connector tubes from the drum averaged 0.51 ppm and the total solids in the saturated header averaged 1.46 ppm. It was evident from these data that one of the samples was incorrect, since it is not possible to produce steam of better quality in the drum than that delivered to the saturated header. At this time the multiple-hole sampling nozzle in the saturated header was first suspected. It was decided to replace the multiple-hole nozzle with a single-hole sampling nozzle identical to that installed in the drum.

From data obtained with the single-hole sampling nozzles located in the same vertical plane through the drum and saturated header, it was noted that the total solids in the steam entering the connector tubes from the drum averaged 0.31 ppm being in line with the total solids in the steam in the saturated header which averaged 0.37 ppm. This established proof that the multiple-hole sampling nozzle gave erroneous results. It was decided to further check its accuracy, and so it was again installed in its original position.

Data obtained from the sampling connections showed that the quality of steam in the connector tubes was essentially the same as that produced in the drum. Steam from the saturated header again indicated total solids in excess of that obtained from samples of steam taken from the drum and connector tubes.

The unreliability of the multiple-hole sampling nozzle was further proved in another test. For this test, the multiple-hole sampling nozzle was rotated in 90-deg steps through 360 deg in the saturated header. Samples of steam were withdrawn at each position. Total solids in the steam samples taken varied from 1.55 ppm to 2.5 ppm. At this time steam produced in the drum contained 0.72 ppm total solids. This evidence again supported the belief that concentration of solids occurred in the multiple-hole sampling nozzle.

In another test, data were obtained from steam samples taken from the saturated header with the multiple-hole sampling nozzle. For these tests, a vent on the sampling nozzle was opened and a large amount of steam was released to the atmosphere while the steam sample was being taken. The results showed that with the vent open the total solids were 0.67 ppm, and with the vent closed the total solids were 2.5 ppm. This would indicate that the use of the multiple-hole sampling nozzle is satisfactory only when sufficient steam is withdrawn by the sampling device to cause a pressure drop between the area from which the sample is being taken and within the sampling device.

The velocity of steam in one section of the saturated header at the connector tube near the drain was calculated to be 2110 fpm. This velocity and pressure drop in the saturated header at this point is a condition which also exists within the multiple-hole sampling nozzle. The combined capacity of the twenty $^1/_8$-in. holes in the sampling nozzle exceeds requirements of the testing apparatus. Only a small portion of the steam which enters the holes is condensed in the testing apparatus. A large portion of the steam escapes from within this sampling nozzle through the first or second holes in this nozzle near the end of the saturated header in the region of lower pressure. The steam makes a rapid right-angle turn to escape from the sampling nozzle at this point, and the solids in the steam are precipitated toward the outlet end of the nozzle and to the sampling apparatus, resulting in the delivery of a concentrated steam sample not representative of the actual steam contained in the saturated header.

From the foregoing tests the authors concluded that unreliable indications of steam purity by the multiple-hole sampling nozzle was caused by unequal pressure distribution in the saturated header of the superheater. It was also concluded that the failure of end superheater tubes was not due to excessive carry-over as indicated by accepted testing procedures, as samples taken at the saturated header drain showed conclusively that concentrations do build up in the ends of the saturated header.

Diesel-Engine Research

LEADERSHIP in Diesel-engine research will be firmly established in the United States with the opening of a new Diesel laboratory at the Oklahoma Agricultural and Mechanical College, Stillwater, Okla., John C. Green, director of the Office of Technical Services, Department of Commerce, said in announcing that OTS and the U. S. Office of Education has allocated a fully equipped Diesel-research laboratory to the school.

As a result of the allocation of the laboratory to Oklahoma A&M, the board of regents of the college is announcing the establishment of the Oklahoma Institute of Technology, a reorganization and expansion of the now existing division of engineering.

The laboratory and its equipment were found by an investigating team at the Klockner-Humboldt-Deutz Diesel-engine plant at Oberursel, Germany.

The laboratory, believed to be one of the world's best equipped, was engaged in the development of two-cycle Diesel engines for automobile and aircraft application involving the loop-scavenging principle. As packed and shipped to the United States, it includes everything necessary to undertake Diesel-engine research in this country.

The laboratory consists of three units: A test-cell unit including eight test cells for engines having from one to eight cylinders, a materials-testing laboratory, and a fuel-injection laboratory. The laboratory has many highly specialized machines such as an oscillograph, x-ray equipment, and a Lindner jig borer with a microscopic adjustment accurate to within $^1/_{400,000}$ of an inch. The Germans estimated the value of the equipment and the laboratory building at 10,000,000 Reichmarks.

The allocation of the KHD research equipment to the Oklahoma college was recommended by at Automotive Industry Advisory Committee with the concurrence of the U. S. Office of Education.

The committee estimated that it would cost about $500,000 to install and house the laboratory and that an annual expenditure of $100,000 was required to properly carry on research. Several other educational institutions were approached but they were willing to take only certain parts of the laboratory. However, the committee felt that the greatest value to the Government would result from keeping the laboratory intact and having it operate as a unit. A final decision was made after careful consideration of all factual data presented by those who could meet the specifications and also desired to operate the laboratory.

Several advantages to the United States appeared evident in the application made by Oklahoma A&M. These, the committee stated were as follows: The college was prepared to house the equipment in a building of its own; it was prepared to spend more than the $100,000 annually to carry on active research; and it would also start research work almost immediately. In addition, Henry G. Bennett, president of the college, submitted a plan whereby one building now being constructed in the Oklahoma A&M's $15,000,000 building program would be used to house the equipment.

OTS Director Green stated: "It will establish a large Diesel research laboratory in a new area—the Southwest—away from the present ones all of which are located in the eastern part of the country. This dispersion of research facilities as we learned in consultations with the Armed Services is just as important as dispersion of production installations if we are attacked during another war.

"Another consideration which prompted the Government to follow the recommendation of the advisory committee is the assurance already received that financial assistance will be obtained from the oil industry in the Southwest just as the eastern laboratories receive encouragement from the Pennsylvania oil industry."

Electric Utility Gas Turbine

THE first gas turbine for an electric utility in this country is under construction at the General Electric Company's Schenectady Works and will be shipped to the Southwest early in 1949, it was announced recently.

A duplicate of the 4800-hp locomotive gas turbine, first announced in March and now undergoing tests, the 3500-kw turbine generator set was purchased by the Oklahoma Gas and Electric Company. It will be installed at the Arthur S. Huey Station, Oklahoma City, Okla.

The new gas-fired unit will be installed in an extension to the present station and operated on natural gas which is available in abundance in the area. The waste heat from the exhaust will be used with a separate heat exchanger to supplement the present boiler feedwater heating system. This will result in additional kilowatt output from the station by releasing part of the heating load from the present installed equipment.

The "straight-through" or in-line arrangement of the compressor, combustion chambers, and turbine was selected for this application. It has been designed for long life and low-cost fuels.

Because there are only two major moving parts, the turbine and compressor rotors, maintenance of the gas turbine is expected to be low.

The unit has been designed for maximum accessibility during maintenance and inspection periods, elements such as combustion chambers which might normally require maintenance being easy to replace.

The new gas turbine will be geared to a conventional 3600-rpm totally enclosed generator with direct-connected exciter. The only water required in the operation of the plant will be a small quantity for cooling the bearing lubricating oil and for cooling the alternating-current generator.

Insulation Material

PLASTIC-foam insulating material that is reported to combine exceptionally low-thermal conductivity with very lightweight, is now being produced by the United States Rubber Company and is available for low-temperature installations.

Present applications include shipping containers for fresh and frozen foods, and commercial and home refrigeration units. Other practical uses are said to be transportation refrigeration in trucks, railroad cars, ships, and airplanes.

Because of the insulating properties of the plastic foam, walls in installations can be made thinner, thus increasing storage capacity. Other advantages of the material, called Flotofoam, are that it is noncorrosive, nontoxic, and self-extinguishing. It will not support mold or bacteria growth and holds its insulating value over a wide range of mean temperatures.

The snow-white plastic foam is available in shredded or block form. The shredded form weights from 0.8 to 1.0 lb per cu ft, and the block form from 0.8 to 1.5 lb per cu ft. Blocks and slabs can be produced in a variety of sizes and shapes to fill cavities, and surfaced with paper, cloth, or resin coatings. The shredded form, which is easy to pour and pack into irregular cavities, can also be supplied in individual containers, ready for installation.

Flotofoam is made from a combination of soluble resins, which are processed first into a liquid, then into a froth, jelled, permanently set, and dried. Air bubbles, whipped in during the frothing process, are permanently trapped, so the finished material is more than 99 per cent air and less than 1 per cent solid. The thermal conductivity or K value of the shredded form is 0.173 to 0.208 Btu/hr/ft^2/°F/in. over a range of mean temperatures from 9 F to 100 F. The thermal conductivity of the block form is from 0.20 to 0.23.

The material is also suitable for flotation purposes, for soundproofing, and for display and novelty uses.

Canning Inspection

THE Army, in recent months, has been opening some of its "canned" guns and other items to determine whether their storage in metal containers has preserved them effectively, the Ordnance Department announced recently. Spot checks, according to the announcement, have shown the guns to be in excellent condition and ready, almost without exception, for immediate use.

The Ordnance Department's inspections are the first of their kind to be reported by the Army although both the Navy and the Air Force have canned and cocooned ships, airplanes, and other equipment.

Based on an idea originated more than 25 years ago at Rock Island Arsenal by a young Ordnance officer, the canning process was perfected and put to use after the past war for preservation of some of the tanks and weapons that were to be retained.

Though the first cost of canning is higher than for other methods of storage, the huge recurring expense of periodic overhaul and regreasing is eliminated, and the need for surveillance, which must be extensive under ordinary methods of storage, is greatly reduced. Other advantages of canning are: Some containers may be shipped unopened to using services; and no tedious time-consuming degreasing is necessary to ready the canned weapon for action.

Among the pieces examined by Ordnance were 90-mm guns, 75-mm howitzers, and 60-mm mortars, as well as telescopes, periscopes, recoil mechanisms, gun directors, generating units, and other equipment. Only slight specks of rust and corrosion were found on any of these although they had been in their cans about two years.

On the basis of inspections made to date, Ordnance Department experts conclude that the canning process is technically successful in maintaining the high quality and usefulness of Ordnance materiel preserved by this process.

ASME TECHNICAL DIGEST

Substance in Brief of Papers Presented at ASME Meetings

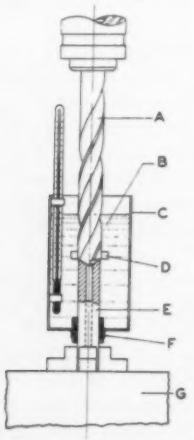
Metal Cutting

Distribution of Heat Generated in Drilling, by A. O. Schmidt, Mem. ASME, and J. R. Roubik, Jun. ASME, Kearney & Trecker Corporation, Milwaukee, Wis. 1948 ASME Semi-Annual Meeting paper No. **48—SA-10** (in type; to be published in Trans. ASME).

The object of this investigation was to determine the amount of heat which goes into the workpiece, chips, and drill at different cutting speeds and feeds. A tubular test bar of extruded Dowmetal was used as the workpiece, thus making the cutting action of the drill similar to that of a single-point tool. The total heat, the heat in the chips, and the heat in the drill were measured separately in a calorimeter.

It was found that the major portion of the heat generated in a metal-cutting operation is carried away by the chips.

Under 200-fpm cutting speed the percentage of heat in the chips will vary with cutting speed and chip thickness; the higher the cutting speed and the thicker the chip, the higher will be the percentage of heat in the chips. Above a cutting speed of 200 fpm the amount of heat in the chips, and also the chip temperature, acquire a constant character for otherwise identical cutting conditions.



CALORIMETRIC APPARATUS FOR MEASURING TOTAL HEAT GENERATED IN DRILLING

(A, drill $^{7}/_{16}$ in. diam; B, 50 cc of water; C, container; D, blades on drill for agitation; E, $^{3}/_{8}$-in. test bar; F, rubber grommet; G, three-jaw chuck.)

At low cutting speeds (around 10 fpm) the amount of heat in the chips will be about 40 to 52 per cent of the total heat generated, depending upon the chip thickness.

At higher cutting speeds (200 fpm and above) the amount of heat in the chips will vary between 60 and 80 per cent of the total heat generated, depending upon the chip thickness. The remaining heat is distributed almost equally to the tool and workpiece. Since the workpiece is usually of larger mass than the tool, its temperature will be low while the heat in the tool is of necessity concentrated in a zone near the cutting edge which at high cutting speeds or under continuous machining will reach a high temperature. This is a frequent contributing cause of tool failure.

Theory and Practice of the Crush-Dressing Operation on Grinding Wheels, by E. C. Helfrich, The Cincinnati Milling Machine Company, Cincinnati, Ohio. 1948 ASME Semi-Annual Meeting paper No. **48—SA-42** (mimeographed; to be published in Trans. ASME).

This paper presents a qualitative analysis of the crush-dressing process based on experimental evidence. The theory developed accounts for the forces involved, power requirements, rate of wheel removal, and the effect of wheel and crusher diameters and surface speed on the crushing process. The equations and data presented will enable the designer to engineer crush-dressing applications more intelligently, and will contribute to a clearer understanding of the process by all who may be interested in applying it. The advantages and disadvantages of crush dressing versus diamond truing are discussed with reference to the physical properties of crystals.

Within the last decade, crush-dressing grinding wheels has been improved and applied to a variety of precision-grinding operations in the modern machine shop. At present crush dressing is rapidly finding its place as a valuable tool in industry; however, diamond truing has not been replaced by any means. While diamond dressing may produce a more accurate surface of revolution, and a somewhat better finish on the work, crush dressing has often proved itself to be the most economical process. Crush dressing, moreover, has the advantages of providing cooler grinding and less normal force, plus its adaptability to the process of dressing intricate forms in the wheel surface. Vitrified grinding wheels lend themselves most readily to crush dressing, and are, in fact, the only type to which this process has yet been applied successfully in commercial practice.

Only the most general case of crush dressing was considered, i.e., external grinding, vitrified wheels, and crusher

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Coupons may be used to purchase pamphlet copies of papers which will be presented at national meetings during 1948 (including the 1947 Annual Meeting). (In ordering give title, author, and paper number. State number of copies wanted.)

Coupon books and copies of papers are obtainable from ASME Publication-Sales Department, 29 West 39th Street, New York 18, N. Y.

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rolls with solid surfaces of revolution. No special cases such as the use of star wheels, Ross dressers, and conical cutters were considered.

Some power readings were taken during the investigation and after proper elimination of frictional and electrical losses the measurements were in close agreement with the theory. All of the readings were taken with a grinding-wheel surface speed of approximately 100 fpm, and no attempt was made to investigate the accuracy of the theory at higher speeds.

Pollution Abatement

Why Pollution Abatement Concerns the Mechanical Engineer, by J. R. Hoffert, Department of Health, Commonwealth of Pennsylvania, Harrisburg, Pa. 1947 ASME Annual Meeting paper No. **47—A-66** (mimeographed).

Pollution from industrial wastes has grown by leaps and bounds in recent years, especially in industrial areas. As a result, many public water supplies have been jeopardized or destroyed; industries have been put to great additional expense for water treatment or have had to seek new locations; important recreational developments have been seriously injured or destroyed; valuable fisheries destroyed; and the people's recreational areas rendered useless or seriously injured.

Pollution should not be judged by whether or not it is decayable material or produces a stench.

Inert fine coal and rock particles from anthracite breakers constitute pollution because they fill up stream channels, block sewers, and interfere with waterworks; nonputrescible chemical wastes which produce tastes and odors in water supplies are serious forms of pollution; spent dyes which color an important recreational stream with all the colors of the rainbow may also be pollution; and any waste which interferes with the legitimate use of the stream by the public is or will be considered by the public and its enforcement agencies to be pollution. Even sterility does not keep a waste from causing pollution if it interferes with the proper use of a stream because of its toxicity, inert solids, color, or other objectionable characteristics.

As an example of the rising standard for the purity of streams, it is pointed out that the present antipollution statutes of Pennsylvania are not limited to the effects of sewage and industrial wastes upon the public health, as was the first act of 1905, but include their effect as well upon public and industrial water supplies, fish and aquatic life, and the recreational use of streams.

A great source of stream pollution in Pennsylvania is the sulphuric acid which pours from the state's coal mines as acid mine drainage. This amounts to about 1,075,000 tons per year.

Since at present there is no known practical general method of treating this drainage, it is the one industrial waste exempted from the provisions of the state law until such a method is discovered.

To hasten this time, two fellowships have been established at the Mellon Institute of Industrial Research of the University of Pittsburgh to try and find an answer. In addition, the state has provided for the diversion at state expense, under certain specified conditions, of acid mine water from clean to already polluted streams.

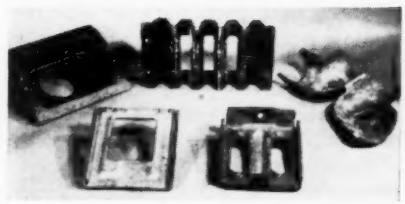
It is pointed out that the mechanical equipment of the large municipal treatment works is so great that there is need for a mechanical engineer to devote his full time to its maintenance.

Stream pollution is of interest to the mechanical engineer because it may vitally affect the production processes or plant practices for which he is responsible. For instance, there is the segregation of certain waste waters; the collection of spent liquids; the recirculation of such things as the cutting oils, the handling of oil-soaked turnings in a machine shop, the lubricating oil in a railroad shop, and all sorts of process waters in industrial plants; the disposal of wash water from a foundry sand-recovery plant; the disposal of boiler blowdown water; and countless other matters which have a vital connection with pollution abatement. His special knowledge may enable him to prevent pollution by rearrangement of plant processes or machine layout; or by recirculation, treatment, and re-use of water. He may be able to cut down the cost of treatment, cause it to "break even," or even produce a profit from a by-product.

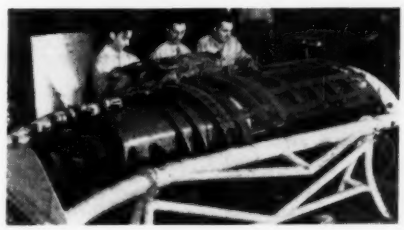
Rubber and Plastics

Plastic Tooling Comes of Age, by Lawrence Wittman, Jun. ASME, Republic Aviation Corporation, Farmingdale, N. Y. 1947 ASME Annual Meeting paper No. **47—A-101** (mimeographed).

Plastic tools in the form of low-pressure-molded reinforced high-strength laminates have proved to possess a high degree of accuracy, stability, durability, and permanency. The simplicity inherent in this method of producing a large class of tools results in substantially



EXAMPLES OF COMPLEX SHAPES EASILY PRODUCED IN MOLDED LAMINATES



LARGE ASSEMBLY FIXTURE SHOWN PARTIALLY LOADED

lowered tool costs and the greater utilization of unskilled personnel. In addition to economies achieved in tooling for full-scale production it is now possible to overcome the obstacle of limited budgets and thus provide good tooling for short-run operations.

Primarily, molded laminate tooling was developed for use in aircraft manufacturing but it is by no means limited to that industry nor to sheet-metal manufacturing alone. This system is applicable wherever special or project tooling is used to form, fabricate, check, or hold components in position for various operations during the manufacturing process. This will especially hold true wherever such tools must incorporate complex shapes or contours.

Furthermore, it is now practical to consistently produce any number of duplicates of a tool which possess accuracy hitherto virtually impossible to attain with steel tooling. This feature will be of significance in dispersed plant operations requiring close co-ordination of tooling and where production volume necessitates duplicate tooling.

Included among the types of contoured fabricating tools now made exclusively of glass laminate at Republic Aviation are the following: checking fixtures, routing fixtures, drill jigs (drill nests, cages, bases), assembly, spot-weld, and installation fixtures. In addition, special tools, not in the category of jigs and fixtures, have been economically fabricated in this medium.

Because of the lightweight and relatively thin cross section, tool size, either small or large, does not impose any limitation on the use of the molding process.

Where tool portability is required, the low weight of laminates becomes an important attribute.

When wisely applied, molded laminates can be made an effective adjunct to, or improvement over, existing methods.

Material characteristics, design considerations, and adaptability of plastic tooling to other industries, are discussed.

Rubber in the Automotive Industry, by R. K. Williams, Research Laboratories Division, General Motors Corporation. 1947 ASME Annual Meeting paper No. 47—A-125 (mimeographed).

It is pointed out that the automotive industry is responsible for consumption of between 70 and 80 per cent of all rubber goods produced.

While the volume of rubber put to automotive use is tremendous, a typical car in the 3300-lb class contains, including tires, in the neighborhood of 440 rubber and synthetic-rubber parts, weighing in aggregate only 175 lb. Of this total 70 per cent is used in tires.

It is in the field of passenger comfort that the rubber in the tires, engine mounts, spring insulators, spring bumpers, crankshaft vibration dampers, seat pads, and many other parts, has done much to improve ride characteristics and reduce passenger fatigue. On cold or rainy days automobile riding would be much less pleasant without the rubber weatherstrips, mats, and seals, or without the insulation attached to the body sheet metal by means of rubber-base cements.

Present-day hydraulic brakes with their tendency to eliminate swerving stops and increase braking safety would not be possible without the rubber wheel and master-cylinder cups which prevent loss of fluid during pressure application or without the rubber seals which keep dust and dirt from scoring or sticking the cylinder mechanisms. Neither would it be practical to conduct fluid from the master cylinder to the constantly moving wheel cylinders without flexible, high-pressure, rubber-fabric brake hose.

Through the development of more moisture-resistant rubbers for wire and cable insulation, and by means of the judicious use of rubber and synthetic-rubber nipples or ferrules at the entrance to the coil and distributor, a great deal of starting trouble has been eliminated.

Virtually all joints and bearings are either sealed from sand and road dirt by means of synthetic rubber, or the rubber itself provides a greaseless medium in which the proper motion can take place. Virtually all joints in the front suspension and steering systems are protected by means of oil-resisting synthetic rubber seals where exposed to road dirt. The same is true of shock absorbers and leaf-type springs.

Some transition from leather to synthetic-rubber seals has taken place and such application should increase for rear-axle, propeller-shaft, transmission, and front-engine seals as the synthetics are improved and their cost is reduced.

Transfer of coolant from radiator to engine is facilitated by use of hose resistant to the deleterious effects of commercial coolants, and the flexibility of the hose has helped prevent fatigue failures at fittings.

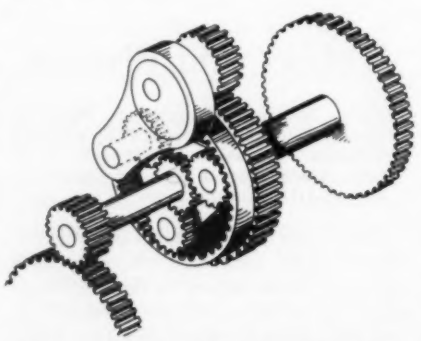
The use of V-type belts for driving water pump, fan, and generator provides a cheap, flexible, and usually quiet driving mechanism without the use of gears or chains. Automatic and semiautomatic transmissions are made cheaper and better through the use of oil-resisting synthetic-rubber caps and packings to seal the various pistons actuating the clutching mechanisms.

How the proper rubber compound for a given automotive application is chosen is discussed in detail.

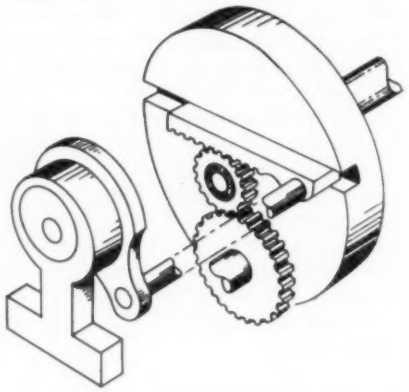
Machine Design

Motion Analysis of Several Intermittent Variable-Speed Mechanisms Featuring Zero or Near-Zero Acceleration and Deceleration Conditions at the Start and at the End of the Motion of the Output Shaft, by G. J. Talbourdet, United Shoe Machinery Corporation, Beverly, Mass. 1948 ASME Semi-Annual Meeting paper No. 48—SA-18 (mimeographed; to be published in Trans. ASME).

In the field of automatic machinery, many interesting intermittent variable-speed mechanisms have been conceived and successfully applied to impart a definite and controlled variable speed to a rotary member. However, most of these ingenious devices are satisfactory only when the speed of operation is relatively low and the inertia of the driven parts is proportionally small.



INTERNAL PLANETARY-GEAR SYSTEM WITH QUADRIC CRANK-CONTROL MECHANISM



FIXED ECCENTRIC AND SLIDING RACK CONTROL MECHANISM

In many instances such devices could be successfully used at relatively high speeds and with appreciable inertia of the driven member provided that the forces acting on the driven members are gradually applied during the period of acceleration. Also, that the energy stored in the driven parts during that period is gradually taken away during the deceleration period, so that no residual energy is left in the driven body when it comes to rest. Then, to obtain these desirable features, the motion of the driven rotary member should meet the following requirements: (1) Negligible acceleration at the start; (2) gradual change in acceleration; (3) smooth change from acceleration to deceleration; (4) gradual change in deceleration; and (5) negligible deceleration as the rotating body comes to rest.

It is evident that these requirements can be met only if, at any instant, the motion of the input shaft is known, whatever its characteristics. This paper, however, confines itself to the case in which the input shaft has a uniform angular velocity throughout its cycle. It also assumes that deflections of parts, gear-teeth backlash, and bearing clearances are sufficiently small so as to have a negligible effect on the motion of the output shaft. Furthermore, it assumes that mass-to-stiffness ratios throughout the system are such as to preclude the existence of resonant torsional vibrations in the range of the desired operating speeds.

Design must therefore consider all the foregoing factors; otherwise, the motion of the output shaft will not follow that given in the analyses.

With these conditions in mind, a flow of energy from the driving to the driven rotating member during the acceleration period and vice versa during the period of deceleration can readily be visualized. It requires of course a reservoir of en-

ergy in the driving member which is most easily obtained by the use of a suitable flywheel on the input shaft.

The purpose of this paper therefore is to present the description and the analysis of several intermittent variable-speed devices in which the features mentioned have been incorporated and proved of real value in the design of current indexing mechanisms and in many other applications.

In general, these devices are the results of the combination of planetary-gear systems, quadric cranks, links, and cams in which one of the members of the planetary-gear system is driven at a uniform angular velocity, while another is given a controlled oscillatory motion, thus imparting to the driven member a definite and variable angular motion. It is also possible to obtain an appreciable dwell of the output shaft when the oscillatory member of the planetary-gear system is actuated by a cam. Furthermore, by the use of such a cam, the output shaft can not only be given a dwell period but also it can be made to reverse its direction of rotation. It all depends on the characteristics of the motion of the oscillatory member of the planetary-gear system.

A New Approach to the Design of Dynamically Loaded Extension and Compression Springs, by Curt I. Johnson, International Business Machines Corporation, Endicott, N. Y. 1948 ASME Semi-Annual paper No. **48—SA-23** (mimeographed).

This paper contains formulas and derivations of a design procedure for dynamically loaded extension and compression springs which permit straightforward solutions to spring problems with minimum assumptions. It is based upon a new method of graphical representation of spring characteristics. This paper also describes a method of cataloging stock springs based on a new graphical representation.

Although the basic formulas for spring design are well known, their efficient use is limited to establishing wire sizes and coil diameters for statically loaded springs. When these formulas are applied to the solution of spring problems involving dynamically loaded springs which must meet specific requirements with respect to operating loads and spring rate, a laborious trial-and-error procedure is involved. Further complication is added to the problem because, in spite of the fact that such springs require a definite minimum volume of material for satisfactory performance, machine designs are executed often without regard to adequate space requirements for these springs. For this reason the author began compiling data to provide the designer with more definite reference material on spring design. While investigating these data, several relationships were discovered that resulted in a more straightforward design procedure eliminating the necessity for numerous assumptions, and it is felt that this information may be of interest to mechanical engineers and designers in general.

This material was developed from a new and more descriptive graphic portrayal of spring characteristics which reveals the presence of a "load constant" which remains the same as long as the wire and coil diameters are unchanged. Since these factors make up the spring index, and since the load constant is determined by the conditions of the problem, it follows that the spring index may also be found for the specific problem, eliminating the necessity for any assumption of the spring index. Hence the coil size selected is dependent upon the maximum load and the load constant or spring index.

Hydraulics

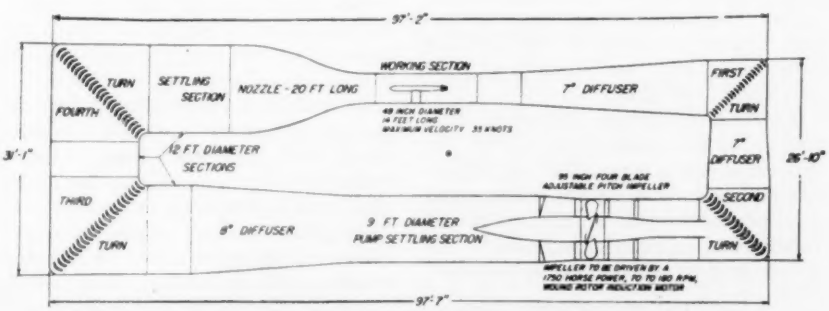
Design of Vaned Turns for a Large Water Tunnel, by A. J. Turchetti, Standard Oil Development Company, Linden, N. J., and J. M. Robertson, The Pennsylvania State College, State College, Pa. 1948 ASME Semi-Annual Meeting paper No. **48—SA-15** (mimeographed).

A 48-in-diam high-speed water tunnel is being built at The Pennsylvania State College to be used by the Ordnance Research Laboratory in the experimental phases of a research program on the development of improved torpedo propellers for the U. S. Navy Bureau of Ordnance. The prime purpose of the tunnel is therefore the testing of model propellers behind model torpedoes. Eight-inch-diameter models are to be tested at speeds up to about 35 knots (60 fps). The circuit for this tunnel consists of the nozzle which produces the uniform high velocity desired for the working section, the 48-in-diam 14-ft-long working section, the diffuser in which the high-velocity stream is slowed down, the four turns, the impeller or pump used to produce the desired rate of flow, and the various other return sections.

A study of vaned turns was made as a part of the research program for the design of the tunnel. Miter turns with guide vanes were the logical choice because of their compactness and small disturbances to the flow. The proportions of the vanes were based on the work of others, and the number of vanes was based on wind-tunnel practice. Structural analysis of the design indicated that the vanes are strong enough, that their deflection is negligible, and that they should not be liable to excessive vibration. Studies of the flow around a 10-in-diam turn with 18 vanes were made in the Penn State experimental water tunnel to determine the cavitation susceptibility and the energy losses and to serve as a final check on the design. It was found that the loss coefficient of the bend is about 0.15, the vanes are safe from cavitation as their critical cavitation index is about 1.1, and that the vanes should be set at an angle of attack of one degree.

The function of the turns in the water-tunnel circuit is to produce a right-angle change in the water direction with as little disturbance as possible. It is of prime importance that the bends, or turns, produce the least disturbance possible in the flow leaving them, not only because such disturbance will result in an energy loss, but also because it may have a detrimental effect on the flow in the following sections. For example, if the first turn of the circuit does a poor job, the flow in the vertical diffuser leg following it may separate or otherwise misbehave.

The work described in this paper was supported by the U. S. Navy Bureau of Ordnance. The paper is based on an informal report of the Ordnance Re-



SKETCH OF 48-IN. WATER TUNNEL AT THE PENNSYLVANIA STATE COLLEGE

search Laboratory of The Pennsylvania State College.

Cavitation Characteristics and Infinite Aspect Ratio Characteristics of a Hydrofoil Section, by James W. Daily, Massachusetts Institute of Technology, Cambridge, Mass. 1948 ASME Semi-Annual Meeting paper No. **48—SA-30** (mimeographed; to be published in Trans. ASME).

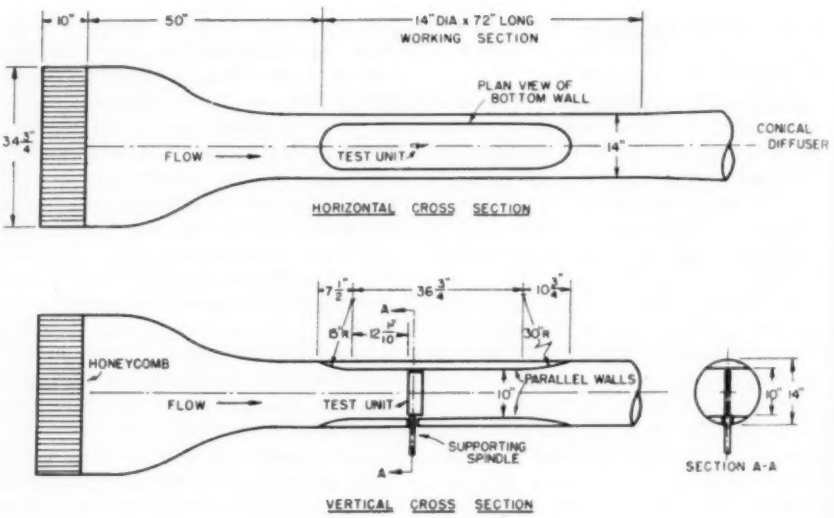
This paper describes "two-dimensional" tests in a water tunnel of a profile identical to the 4412 airfoil section of the National Advisory Committee for Aeronautics. The tests included photographic observations of the inception and growth of cavitation as influenced by velocity, pressure (submergence) and angle of attack, and measurements, during cavitation-free operation, of the hydrodynamic forces and moments as functions of Reynolds number and angle of attack. The relation between the angle of attack and the value of the cavitation parameter at which inception occurs is shown for each face of the hydrofoil. The effect of profile geometry in causing cavitation, and the significance of distinctly different types of cavitation obtained with change in variables are discussed. Convenient curves are given showing the submergence required to avoid cavitation for different velocities and angles of attack. The measured hydrodynamic characteristics are presented in graphical form and are also compared with previously existing data from wind-tunnel tests of a finite aspect-ratio span. The experimental procedure and its reliability in indicating true infinite-aspect-ratio characteristics is discussed.

In 1943 a test program was undertaken in the High Speed Water Tunnel of the California Institute of Technology which provided an opportunity for making a detailed study of the characteristics of a hydrofoil that included cavitation as well as the normal hydrodynamic data. This program was initiated at the request of the David Taylor Model Basin with the objective of investigating, in general, the testing of small-scale hydrofoils in a water tunnel of the Cal-Tech type under both cavitating and noncavitating conditions.

For these experiments, the test installation in the water tunnel was arranged to provide as nearly as practical two-dimensional flow so that all observations and measurements would correspond to the infinite aspect-ratio condition. The investigations included the following:

1 Visual and photographic observations of the cavitation on the hydrofoil as it appeared, developed, and disappeared, as functions of both velocity and angle of attack.

2 Measurements of the hydrodynamic forces and moments acting on the hydrofoil, also as functions of velocity and angle of attack. The force measurements were limited to the noncavitating conditions. The results of both categories of tests are presented, together with a discussion of the test procedures used.



HYDROFOIL-TEST INSTALLATION

Safety

Integrating Safety Engineering in Engineering College Curricula, by H. W. Heinrich, Mem. ASME, The Travelers Insurance Company, Hartford, Conn. 1947 ASME Annual Meeting paper No. **47—A-30** (mimeographed).

The need and value of integrating safety engineering in the curricula of colleges that teach engineering subjects and to deal with practical ways and means whereby such integration may be accomplished is emphasized.

It is pointed out that the over-all objective of engineering education must include safety. For example, in no other way could a student become adequately familiar with the tools and skills required for technical competence. Equally significant also is the objective relating to economic aspects and social significance of the engineering profession. Safety is essential because it permits the engineer to function physically unimpaired.

Research has proved that a safe industrial operation is also efficient productively, and that inefficiency, from a production viewpoint, is accompanied by high accident frequency and cost.

Integration need not require additional courses, subjects, or time. All that is required is the following: First, amend or revise the course and subject outlines of existing curricula so as to include appropriate references to safety engineering; second, provide for the benefit of the instructor, suitable data and examples, together with references to available text; and third, provide for the instructor a manual or teacher's guide descriptive of the general subject of integrated safety engineering plus suggested methods of application to specific courses and subjects.

It will be seen that integration requires revision and amendment rather than addition. The instructor selects certain examples and problems of value from a safety-engineering viewpoint instead of those of a general nature. The safety-engineering examples and problems thus selected for study, of course must be, and fortunately can be, fully as instructive with regard to the objectives of the course or subject. For example, in machine design the student can learn as much about the functioning of cams and levers from their application to safety devices as he can from general applications. In English, safety engineering provides fruitful opportunities for library research, recording of facts, evaluation of written material, and the composition of technical reports. Other subjects lend themselves equally well to the thought of substituting examples and problems in safety engineering for

those of a general nature, thus adding to the sum total of acquired knowledge without adding time or effort.

In addition to integrating safety engineering directly in engineering curricula, the college structures and grounds should be modernized as to means of preventing personal injury and fire. So too should the equipment of the laboratory and gymnasium.

The ASME Standing Committee on Safety is presently engaged in a project of this kind. Its procedure is exactly in accordance with the three steps suggested in the foregoing.

Personal Factors for Developing Safety Consciousness, by Walter A. Cutter, New York University, New York, N. Y. 1947 Annual Meeting paper No. 47—A-31 (mimeographed).

The gap which has existed between the engineering and the human sciences must be closed. This will be done best by dealing with the human aspects of production with the same thoroughness as with engineering. Accidents represent inefficient subtractions from successful productions. It will be found that a comprehensive and constructive approach to the whole subject of personal factors, involving such elements as the physical and mental health of workers, their proper training and supervision, the developing of a liking for their work, and of a sense of personal significance, will decrease accidents and add to production.

The foundation of a significant safety consciousness is laid far deeper than simple adherence to a code of safe practices. It comes about, in its best sense, when all who are concerned in an undertaking—management, supervision, and the working force—understand all the conditions requisite to efficient production and are willing, by necessary training and standards of practice, to avoid those inefficiencies which lead to accidents and other losses. Putting this into the form of a verbal equation it may be expressed as follows:

An enlightened, foresighted, sincerely safety-conscious management in both word and deed plus proper personnel practices, selection, and placement, including proper inquiry into the mental and physical health of employees, their training, and proper assignment plus a corps of workers who are trained, well disposed toward their work, who understand that basically efficient and safe performance is for their benefit, and who are willing to learn how to keep safe and try to keep safe plus safe machines, materials, and processes plus that degree of safety organization which is best fitted to the particular firm, plant, or industry, and which is organized on the basis of accident prevention being an indispensable adjunct to worker welfare and successful production equal safe and efficient, as well as uninterrupted production.

Modify any of the terms of this equation to a substantial extent, or subtract any one of them, and the equation is out of balance. Accidents and other losses will be an inevitable result.

The personal factors for developing safety-consciousness are fully discussed.

Heat Transfer

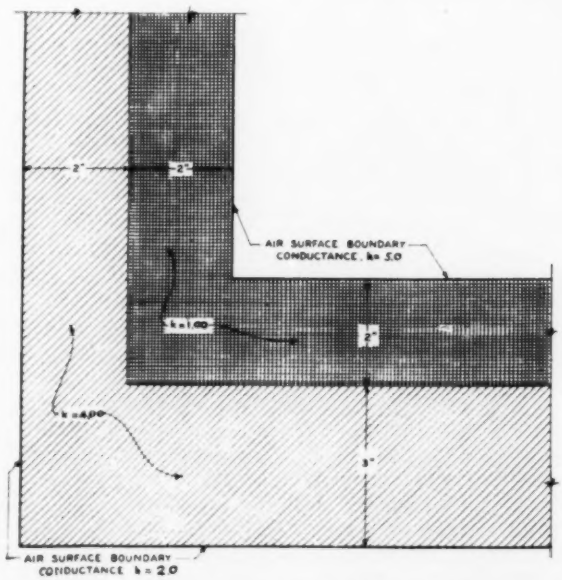
Heat-Transfer Temperature Patterns of a Multicomponent Structure by Comparative Methods by Carl F. Kayan, Mem. ASME, Columbia University, New York, N. Y. 1948 ASME Spring Meeting paper No. 48—S-10 (mimeographed).

Prediction of the temperature patterns for a multicomponent complex wall between two heat-transfer fluids is rendered difficult when the isotherms themselves are distorted in irregular fashion.

The multicomponent structure studied in this paper is a thick corner composed of two different materials of unequal thickness and of widely differing conductivity. The fluids on the inside and outside surfaces, representing the high-and-low temperature levels, respectively, are considered as having different boundary conductances. In this study the wall materials are considered homogeneous and of constant conductivity (i.e., independent of temperature). Joint resistance between adjacent layers is disregarded, and the boundary conductance for each fluid is considered to be uniform over the surface in question.

The cross section of the corner as studied represents a two-dimensional heat-transfer problem, with assumed thermal conductivities of 1.00 and 4.00 Btu/(ft²)(hr)(F/in.) for the inner and outer layers respectively. The inner layer is uniformly 2 in. thick, and the outer layer 2 in. thick on the one side, and 3 in. thick on the other. The section studied runs 10 in. in each direction, as measured from the outside corner. A surface conductance, h_a = 5 Btu/-(ft²)(hr)(F) has been assumed for the inside surface conditions, and h_a = 2 for the outside, as representative of conditions due to air, for example. The heat flow is presumed to be in steady state from the inner fluid to the outer fluid, on the basis of the prevailing temperature difference. The composite structure is one such as may be found, for example, in refrigeration practice.

It must be emphasized that the results of the present analysis must be recognized as being based solely on the assumed basic data, i.e., thermal conductivities and boundary conductances. It is of course further understood that the values assumed for the analysis have been selected arbitrarily.



CROSS SECTION OF CORNER SHOWING TWO-LAYER CONSTRUCTION

This paper reports the comparative results for this two-dimensional steady-state problem by several comparative methods. The philosophy underlying these is that of the so-called resistance concept of heat transfer. Herein specifically the flow of heat in thermal cir-

cuits is regarded as behaving in parallel fashion to the flow of current in electric circuits, as expressed by Ohm's law. Accordingly, the characteristics of the heat flow are established by analogy through the study of an equivalent electric system. Determination therefore of the isopotential lines through the electrical study permits translation into equivalent isothermal lines, and thereby permits establishment of the temperature distribution in accordance with the impressed over-all temperature difference.

The paper includes the experimental "geometrical" and the network electrical analogies, as well as the solution of the equivalent electrical network by the process of arithmetic iteration.

Wood Industries

Laminating for Small-Boat Construction, by Donald F. May, Puget Sound Naval Shipyard, Bremerton, Wash. 1947 ASME Annual Meeting paper No. **47—A-68** (mimeographed).

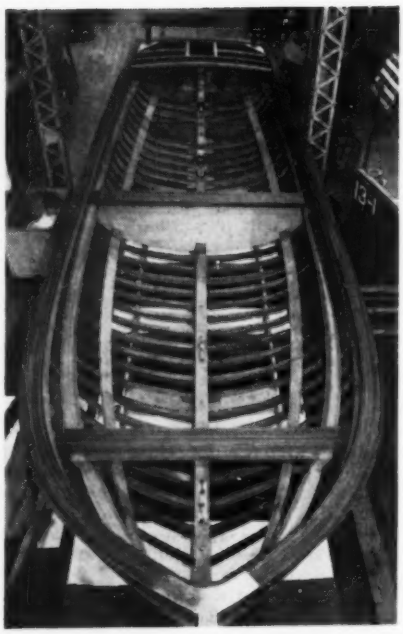
Since 1943 laminated marine parts for small-boat construction have been accepted by many builders who were formerly skeptical of this type of construction.

The laminating of tanks for water, acids (except hot sulphuric), and other liquids, built at the Puget Sound Naval Shipyard have been dependent on glue alone to hold them together with no metal used in construction. There are no joints to leak.

The wide acceptance of laminated construction for small boats was because the office of Production Research and Development in 1943 saw that stocks of solid structural parts were dwindling and set up two plants to develop and introduce laminated parts for small boats.

When these plants were first set up, laminated members for marine use were frowned upon by all old-time boatbuilders and the problem of selling the idea was harder than developing the process originally. Laminating for small-boat construction has now been accepted by a great many manufacturers of pleasure boats as well as work boats. The Puget Sound Naval Shipyard built hundreds of laminated parts such as keels, stems, aprons, shaft logs, and horn timbers, for construction of small boats. These boats were used in all parts of the world under all conditions and have proved, upon inspection, to be superior to solid members.

In marine work even the garboard planks can be laminated in a jig to the desired shape, saving a great deal of



ALL-LAMINATED BOAT

time and material. It was pointed out that difficult objects such as station-wagon parts are the ones that should be laminated, and there is no limit to what can be laminated if time and thought are given to the problem.

The pioneer work at the Puget Sound Naval Shipyard retained all the rigid controls and requirements necessary to guarantee a waterproof glue line. Bureau of Ships specifications call for white oak throughout the structural members of all small boats, which increases the laminating problems.

In laminating timber products for marine use, low-temperature phenol, resorcinol, and melamine resin glues are the only types suitable, and not all of these meet requirements. At present, all acceptable glues are of the liquid type, and they are usable only for about 60 days, or 90 if kept in cold storage. Because precision equipment is required to maintain the necessary control, it is generally impractical for each manufacturer of small boats to do his own laminating.

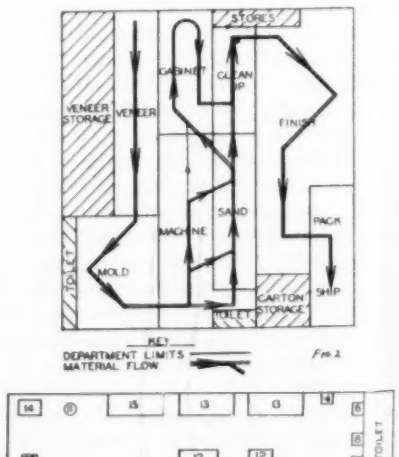
Rough planing of lumber is an essential first step in laminating, and proper amount of glue and pressure are important. Softwoods require a pressure of not less than 100 psi and pressures up to 300 psi are not harmful to the glue line.

For spreading glues a spreader, with a micrometer setting, on the spreading rolls is necessary, and it is important to consider ease of cleaning the glue from the spreader when choosing a glue. Time and temperature for curing are also important. The Navy recommends 150 to 210 F and ten hours in the curing chamber after the innermost glue line reaches this temperature. The humidity should be 85 per cent to protect laminations from checking and shrinking while curing.

Factory Layout and Equipment for the Mass Production of Molded Plywood Furniture, by E. Sigurd Johnson, Mem. ASME, Salem, Va. 1947 ASME Annual Meeting paper No. **47—A-44** (mimeographed).

The wartime developments in molded plywood for boats, aircraft, and other military products are now being put to peacetime use in the manufacture of furniture. Since the product is different from the conventional in design and construction, many of the manufacturing problems are new and without precedent in furniture manufacture. This paper describes how to design a plant layout, and select or develop equipment for the mass production of molded plywood furniture.

Molded plywood can be defined as plywood formed of double curvatures or such high-degree curves that fluid or omnidirectional pressure must be applied to procure a satisfactory glue bond. Wartime demands for molded plywood spurred the development of processes and methods that are all well adapted to produce parts for certain types of furniture. Although molded plywood fur-



EQUIPMENT LAYOUT OF MACHINING AND SANDING DEPARTMENT OF A MOLDED-PLYWOOD-FURNITURE MANUFACTURER

niture has been designed and produced for a number of years, the quantity production of this product is a postwar development of several companies.

The space requirements and layout of a plant will vary from the conventional type of furniture factory to a considerable degree. Therefore the setting up of a new plant requires a complete analysis of all operations in order to insure proper location of departments, material storage areas, services, and equipment to provide the proper space for each operation and to obtain minimum travel of material through the plant. Because of the newness of this type of manufacture, service lines and equipment should be installed so that moves can be made easily whenever a change in operational procedure requires shifting machine locations or adding new pieces of equipment.

Standard woodworking equipment can be used for most operations; but ingenuity must be exercised in developing jigs, forms, and additions to these machines to handle efficiently the bulky curved parts encountered in molded plywood furniture production. When an operation cannot be done efficiently on a standard piece of equipment, a special machine should be designed and built for the particular operation involved. A typical plant will require several of these single-purpose machines which will pay for themselves in labor savings within a few months after installation.

Departmental layout, material storage areas, service lines, equipment layout, and equipment specifications are discussed in detail.

Materials Handling

Materials Handling in the Distribution Department of the Western Electric Company, by F. C. Podboy, Western Electric Company, New York, N. Y. 1947 ASME Annual Meeting paper No. 47—A-94 (mimeographed).

At the close of World War II, the Bell Telephone System was faced with a problem of expansion that was exceedingly complex in nature and magnitude. A program was necessary for the rehabilitation of the all-essential distributing warehouses, which had become outmoded during the war years. Naturally, they were inadequate to handle the tremendous volume of new business.

The armed forces took full advantage of every phase of the unit-load principle of materials handling. The concern of the industrial world was centered about the point as to how to apply this principle in solving their own problems; in this case, the distribution of telephone equipment.

The paper describes in detail the various arrangements and methods employed to increase economies of operation. This made it possible to handle a steadily increasing volume of business while at the same time tightening up on the delivery interval and reducing the investment in supplies by servicing a greater area on a 24-hr basis.

It is interesting to note that the company changed its conception of space from square feet of floor space to cube area.

Instruments

Diagnosing Engine Troubles in Flight, by James W. Wheeler, Mem. ASME, Sperry Gyroscope Company, Inc., Great Neck, N. Y. 1948 ASME Semi-Annual Meeting paper No. **48—SA-8** (mimeographed).

This paper discusses briefly the effect of engine troubles on airline operations, and compares present methods of locating troubles with the use of the engine analyzer. The engine-analyzer method of operation and design criteria are shown to have resulted in excellent performance in airplane tests which have proved the basic advantages of diagnosing engine troubles in flight.

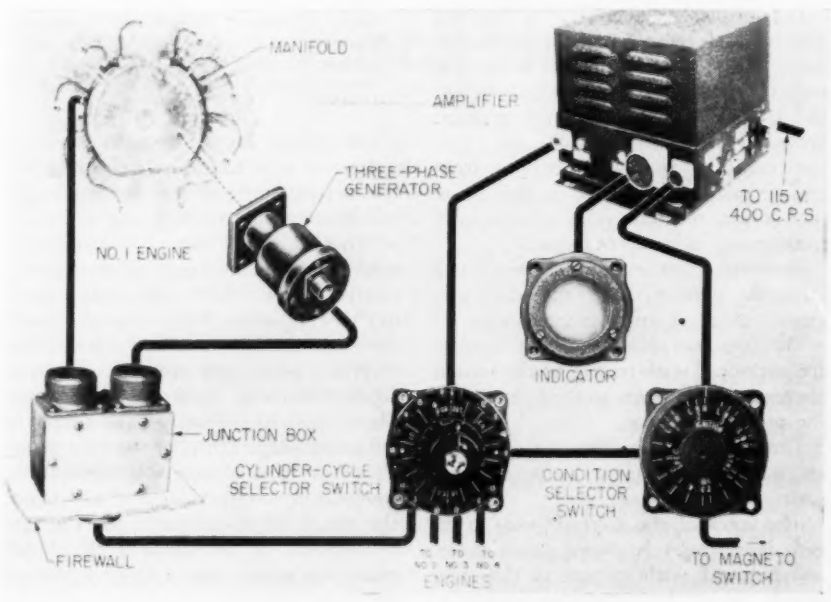
The engine analyzer permits a different approach to the problem of engine-component troubleshooting. Instead of operating as "go-no-go" gages, by which specific function of components may be checked one at a time until a source of trouble is located, the new analyzer makes it possible to find where a trouble is located, and to determine why trouble is occurring. The ability to make an over-all check is very important; if several detail tests must be made on each component, the time required becomes excessive. This is particularly true if the component is not available for the detail checks, which is usually the case when it is mounted on the engine.

Location of troubles is rapid with the analyzer, because the condition (i.e., ignition difficulty or mechanical difficulty) suspected on a particular engine can be selected by the operator with one switch, while with a second switch he can locate and examine the particular cylinders in which trouble is occurring.

The analyzer presents the data on a cathode-ray-tube screen. The pattern on the screen can be interpreted simply by comparison with typical patterns obtained under known conditions.

The most important reason for finding engine troubles in flight is to obtain increased flight utilization of the airplane. An appreciable part of the time now used in servicing airplanes is used in locating troubles. With the analyzer many of the troubles may now be located in flight, and additional flight time is thus made available. Furthermore, the elimination of needless servicing (due to improper diagnoses of troubles) results from the use of the analyzer.

Location of engine troubles is generally done by separating the engine functions into a number of subdivisions equal to the number of cylinders in the engine. This subdivision is best made as a function of engine-crankshaft angle;



BASIC COMPONENTS OF ENGINE ANALYZER

a principal feature of the engine and the item to which all other components are spatially related is the engine crankshaft. The location of a particular crankshaft angle must be definite, exact, and simply performed by the user. It is essential that localizing be as easy and rapid as possible, and that results should be capable of direct and simple interpretation.

A Remote-Indicating Pressure Gage for Aircraft, by R. G. Jewell, General Electric Company, Lynn, Mass. 1948 ASME Semi-Annual Meeting paper No. **48—SA-12** (in type; to be published in Trans. ASME).

The indication of aircraft-engine oil and fuel pressures presents numerous problems. A brief study of existing gages shows that the two most serious problems are low temperature and engine vibration. A remote-indicating pressure system has been developed to overcome these difficulties.

The system makes use of a bellows-operated transmitter which utilizes the so-called second-harmonic principle to transmit a signal to a ratio-type indicator on the instrument panel. This principle requires a source of alternating-current power for its operation and the present equipment is designed for 400-cycle power supplies.

In describing this system, the recently introduced method for analyzing measurement equipment is useful in gaining a clear understanding of its fundamental functions. The system is divided into three functional groupings, namely, the primary detector, the intermediate means, and the end device.

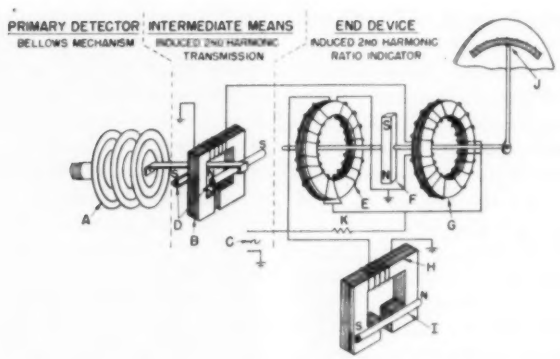
The primary detector is a bellows which was developed specifically for this gage. The spring rate of the bellows is such that it requires no control spring, and the deflection with rated pressure applied is approximately $^1/_{16}$ in. Life tests made by cycling the bellows from zero to rated pressure and to zero show that several million cycles are necessary to show any evidence of failure.

The intermediate means consists of a saturable reactor, two movable permanent magnets, and a power source.

The two movable permanent magnets are positioned with respect to the saturable reactor in response to the deflection of the primary detector.

The end device consists of two receivers, a permanent magnet, a pointer and scale, and a generator.

The cores of the receivers used in the end device must be round, continuous, and centered with respect to the shaft which carries the permanent magnet so that the forces on the permanent magnet will be balanced and not cause a torque on the shaft as the magnet and shaft are rotated.



FUNCTIONAL ANALYSIS DIAGRAM OF REMOTE-INDICATING SYSTEM
(A, bellows; C, power source; B, H, saturable reactors—generators; E, G, saturable reactors—receivers; J, pointer and scale; D, I, F, permanent magnets; K, resistor.)

The primary detector and the saturable reactor, and magnets, are assembled into one case and termed a transmitter.

All of the basic elements of the end device plus the terminals for the power supply are mounted in another case and comprise the indicator.

The remote-indicating pressure gage described meets the requirements for mounting the transmitter directly on the engine. The size and weight of the transmitter and indicator have been kept to a minimum, and the over-all installed weight is reduced by the use of a single connecting lead between the transmitter and the indicator.

Thermocouple Pyrometers for Gas Turbines, by Andrew I. Dahl and Ernest Fiock, National Bureau of Standards, Washington, D. C. 1948 ASME Semi-Annual Meeting paper No. **48—SA-29** (mimeographed; to be published in Trans. ASME).

The recent development of the gas turbine as a practical power plant for applications on land, sea, and in the air has been accompanied by the wide use of thermocouples for indicating gas temperatures in the range up to approximately 2000 F. Many problems related to this application have assumed considerable importance, in both the evaluation of power-plant performance and in the development of satisfactory controls. These include evaluation, in terms of indicated temperature, of the heat transfer to or from the sensing element by conduction, convection, and radiation, the effects of gas velocity, and the rate of response of the element to sudden changes in temperature. Of these diverse problems, this report deals only with the control and evaluation of the radiation correction, and with the response rate of thermocouples.

Research sponsored by the Bureau of Ships at the National Bureau of Standards on the measurement of gas temperatures has led to the development of a shielded thermocouple suitable for use in gas turbines. In such power plants the gases are normally hotter than the surrounding walls, so that radiation from the sensing instrument to the walls may cause considerable error. The conventional method of shielding by coaxial tubes has the obvious disadvantages of large size with attendant problems of installation, undesirable disturbance of gas flow, and slow response to sudden changes in gas temperature. Even more effective shielding, without these disadvantages, can be obtained by pressing a small shield of silver, gold, or platinum directly on an oxidized junction of base-metal thermoelements.

This report describes the construction of such shielded junctions, apparatus used in determining their performance in streams of exhaust gas, and preliminary results of service tests in operating gas turbines. The ranges of temperature over which silver- and platinum-shielded base-metal junctions may be used have been established, and charts have been developed for evaluating the small radiation corrections which are required for junctions with these shields over the range of gas and wall temperatures experienced in gas turbines.

The rates of response of various junctions have been determined. Junctions with pressed shields respond with all the rapidity that is needed for establishing thermal efficiency, but not even bare junctions of adequate mechanical strength respond with the rapidity which is desirable for control purposes. Means for increasing the rate of response by using special junctions in series are discussed.

COMMENTS ON PAPERS

Including Letters From Readers on Miscellaneous Subjects

Welded Joints

To the Editor:

Recently, articles have been published lamenting the restrictions placed upon welding structures. One author wants a 100 per cent joint-efficiency allowance without x-ray examination, because all welds tested in tension had failed outside of the weld. He compares welded joints with riveted joints, pointing out that the full calculated efficiency of riveted joints was permitted. The writer's experience in the field of welded boiler and pressure-vessel construction definitely does not support the viewpoint fostered in these articles.

The factors involved in the construction of a riveted joint are so greatly different from those involved in welded structures as to make a comparison between the two of little value. The actual efficiency of a particular riveted joint can be calculated with reasonable accuracy. It is relatively simple to check the alignment, fit-up, and completion of workmanship in a riveted joint so that there are practically no unknown factors, provided the material conforms to normal standards.

A poor weld is often deceptive in its appearance. As a matter of fact, a very good-appearing weld is often produced by using a low-set welding machine, which results in a joint having improper penetration. Welding is indeed an art, and the character of a weldment depends to a great degree upon the procedure followed and the technique of the particular welding operator. Even though a well-qualified procedure is used and experienced operators are employed, far from perfect welds often result. Faulty grounds which reduce the current below the value anticipated by the operator in setting the machine are common sources of difficulty. Poor work turned out by one welder was traced to the fact that his lead cable was lying in coils which built up a counter electromotive force and choked the current. Operators are often reluctant to readjust the setting of the machine if they are working in an awkward position or location, even though the work varies sufficiently to warrant such adjustments.

In large welding shops, where all welders are subjected to periodic tests, it is often surprising to note the number of veteran operators who fail to produce specimens which pass the standard face, root, and side bend tests. Recently, a number of new men were hired in a pressure-vessel shop who were all considered well-qualified welders, as they had many years of experience in ship construction, pipe-line, and structural work. Out of 25 such men, who were tested in accordance with the ASME Unfired Pressure Vessel Code, only two were successful in their first attempt to qualify. Others were able to pass these tests after periods of training, but quite a few never mastered the technique.

Recent tests of weldings by a leading eastern fabricator discloses another condition, often overlooked when viewing the character of a weldment from the results of tension tests. It was demonstrated that butt welds, having a static strength of 83 per cent of the base material, had a fatigue strength of only 33 per cent, while those welds developing static strengths of 72 and 58 per cent resulted in fatigue strength of 15 and 10 per cent, respectively. It was also demonstrated that the fatigue strength of right-angle double- and single-fillet welds is comparatively low.

The percentage of radiographed welds which are found to be unsatisfactory in boiler and pressure-vessel construction is surprisingly high. In boiler and pressure-vessel construction, whether or not x ray and stress relieving are employed, the finished structure is subjected to hydrostatic and hammer test. In structural work, it is often impractical to apply a test upon the weldment.

The present boiler and pressure-vessel code permits a welded-joint efficiency as high as 95 per cent, and allows an efficiency of 85 per cent for welds which are not stress-relieved or x-rayed. These joint-efficiency allowances are most liberal, and the writer's observations indicate that these efficiencies can only be permitted safely when the welding is under the surveillance of a competent, conscientious inspector. Further liberalization of the limited restrictions now placed upon welding should not be considered until development of the art warrants such changes.

The progress of welding during the past two decades has been remarkable, and it will no doubt continue. However, as yet, we have not reached the stage where blind confidence can be placed in a welded structure.

E. B. Lund.[1]

[1] Engineer, Engineering Department, The Ocean Accident and Guarantee Corporation, Ltd., Memphis, Tenn. Mem. ASME.

Aircraft Gas Turbine

Comment by H. E. Grantz[2]

The authors have performed an outstanding engineering achievement in the design and development of the TG-100A Turboprop engine. Many important events have transpired in the further development of the TG-100 engines since this paper[3] was written.

A total of 104 flights have been completed by airplanes powered by TG-100A engines. These flights have been made to altitudes up to 40,000 ft and over a wide range of powers and air speeds. The only serious difficulty experienced with the TG-100A engines on all of these flights was one failure of an element in the control linkage. Considerable information was obtained regarding control requirements of Turboprop engines. The constant-speed propeller-control system, as used with piston engines, is not satisfactory for use with a Turboprop engine.

An improved model designated the TG-100B engine, has been designed and is being manufactured by the Aircraft Gas Turbine Division. The results of the flight tests, as well as development tests were applied to the design of this improved engine.

Some of the major problems which still require considerable attention are short periods between overhauls, short life of several critical parts, and the further evaluation of the combined control characteristics of the propeller and gas turbine in combination.

[2] Project Engineer, Aircraft Gas Turbine Division, General Electric Company, West Lynn, Mass.

[3] "An Aircraft Gas Turbine for Propeller Drive," by Alan Howard and C. J. Walker, Mechanical Engineering, vol. 69, Oct., 1947, pp. 827–835.

It is often difficult to appreciate the magnitude of the problems which must be solved in developing the first of a completely new type of engine. The authors deserve a great deal of credit for the work they have performed in their solution of these problems.

COMMENT BY D. F. WARNER[4]

The development described in this paper was the first propeller-drive version of a gas turbine in this country. A limited number of TG-100B Type of Turboprop engines to the same aerodynamic design as that laid out by the authors but incorporating certain mechanical changes and a new control system are yet to be built. These units are looked upon as tools with which to investigate the Turboprop controls which remain a live problem.

Due to the fact that ever-increasing gains in economy are predicted for the reciprocating engine highly supercharged in various manners, the target in economy at which the Turboprop designer must now shoot lies in fields away from the simpler cycles. The starting problem in the simple-cycle Turboprop engine of larger capacities especially is not an easy one.

It is unwieldy when done electrically, so much so that higher-capacity simple-cycle units must incorporate other starting means, not existing, practically, today.

[4] Design Engineer, Aircraft Gas Turbine Engineering Division, General Electric Company, West Lynn, Mass.

REVIEWS OF BOOKS

And Notes on Books Received in the Engineering Societies Library

Powder Metallurgy

POWDER METALLURGY ITS PHYSICS AND PRODUCTIVITY. By Paul Schwarzkopf, The MacMillan Co., New York, N. Y., 1947. Cloth, $6^1/_4 \times 7^1/_2$ in., 379 pages, figs., and illus., $8.

REVIEWED BY A. J. LANGHAMMER[1]

THIS book is an excellent work. It is a fine contribution for technical men and, in particular, for metallurgists and physicists working in powder metallurgy. As a textbook it is outstanding and well-suited for postgraduate work.

Dr. Schwarzkopf's style is impressive and one soon appreciates that the author is well-versed in both the theory and practice of general powder metallurgy. Presentation is made in a manner totally coherent, thoroughly understandable, and easy to read. The theory of powder metallurgy is covered quite thoroughly along with the reserved comments and conclusions of the author. Contained in the book are many photographs, charts, data, bibliographies, and references. The theories of other authors are faithfully recorded, particularly as applied to the major items of sintering and compacting, or briquetting. The author definitely credits the results and conclusions of early investigators, the work of other authors, and pays handsome tribute to colleagues and collaborators.

Briefly, what may be termed the various branches of this subject are all covered in considerable detail, and include porous and dense products, ferrous and nonferrous units; also hard metals, refractories, friction parts, and a number of specialty items. Whereas there are no superfluous words, the work is, nevertheless, quite complete, particularly with regard to details on important items.

Raw materials or metal powders are often underrated. Too many engineers and inventors treat them loosely with resulting ill-favor. Dr. Schwarzkopf does a thorough job in describing and evaluating the different methods and processes of each powder manufacture. The importance of grain structure and the influence of the various characteristics such as mesh size, grain shape, hardness, malleability, and growth, are fully described. Emphasis is given justly to iron powder and copper powder as these two powders are used in the largest volume in industry today. Individual characteristics and behavior, as well as the general characteristics of these two materials in powder form, are properly stressed.

Normally, powder metallurgy involves the operations of mixing, briquettingor compacting, heat-treating or sintering, and finish-forming or sizing. As treated by the author each operation is dealt with brevity.

Mixing is probably the least important of the group, but the author discusses this operation in detail, and lists the type of equipment employed, along with deviations required fordifferent materials.

Briquetting is a major item, and Dr. Schwarzkopf's chapter includes listing and discussion concerning the briquetting presses, tool or die design, the theory and practice involved in making a simple briquette, as well as one of more complex design. The theory of compacting, effects of poor flowing characteristics of the powder, variation in briquette density, the merit of single and double end compression, and the general practices are well-covered.

Integral with briquetting is the matter of tool design, and this very special art is given proper emphasis, and both described and illustrated. Powders of different metal behave differently. Their behavior, as well as related factors are dwelt upon.

Heat-treatment or sintering, like briqueting, is a major operation, and proper space has been devoted to informative data on the equipment and the factors involved. Temperature and time are, of course, pre-eminent, and their effects are discussed and illustrated by charts and data. A vital factor, too, is the matter of atmosphere, and the author describes the various types, their merits and demerits for a certain application, and over-all effects on the end products.

Sizing, or re-pressing, is second in importance only to the two foregoing operations. The author describes various presses and equipment, dwells upon the features of die design, and by data and charts illustrates the effect on physical properties. What may be termed special sizing to effect greater density is also described and discussed. Different approaches to sizing are discussed, press capacities, production per hour, and such matters as proper die steels are incorporated.

One division in powder metallurgy is that of porous products versus units that are semisolid. Another is that of ferrous and nonferrous products. Appreciable space is devoted to the discussion of the metals in both divisions concerning

[1] President, Amplex Division, Chrysler Corporation, Detroit, Mich.

processing and the characteristics of the end products. Naturally, processing varies with the materials and also as regard to the porosity requirements. The author is excellent indeed in his description and discussion of the many variables and factors involved.

Hard metals are of immeasurable importance to industry. They have requirements that differ from those that occur in the processing of iron and copper, for example. Tungsten carbides have been developed and now include other elements. The various metals, their manufacture and treatment, the presses, equipment, and processing are fully and admirably covered. Much data of both general and specific nature are included with illustrations and charts.

Other products treated are magnets, friction material, contact points, and electronic cores. This covers a wide range of metals and nonmetals, as well as specific processing.

Characteristics, capacities, electrical properties, friction characteristics, and similar factors are duly described. Included is a treatise on the equipment and processes as well as comprehensive data showing the results of different alloys on different treatments.

Powder metallurgy, in total, may be considered in this light. First, as composed of products that cannot be otherwise achieved, and, second, regarding products in which they are competing with those of cast or solid metals. Whereas, great over-all progress has been made, the latter group in the more recent years is fast moving ahead. Dr. Schwarzkopf devotes considerable time and data to the processing and production of units in the latter group.

The author assays to paint a forward picture of the hidden potentialities of powder metallurgy, and in this the reviewer goes along.

We like Dr. Schwarzkopf's book. Throughout the entire work it is a fine mixture of theory and practice, all given in a smooth and pleasant manner that makes for confidence.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by ASME members for a small handling charge. The Library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

Books Received in Library

ALLOYS FOR USE AT HIGH TEMPERATURE—REPORT ON VISIT TO GERMANY AND AUSTRIA. By W. J. Robinson. Mapleton House, Brooklyn, New York, N. Y., 1947. Paper, $5\frac{1}{2} \times 8\frac{1}{4}$ in., 79 pp., diagrams, charts, tables, $4.50. This report contains the information gathered by a group which studied the conditions to which metallic materials were exposed in the German gas-turbine and jet-propulsion engines. It describes the materials which had been developed to meet these conditions. Testing methods and machines are also discussed.

ANALYSIS AND SYNTHESIS OF LINEAR SERVOMECHANISMS. By A. C. Hall. Technology Press, Massachusetts Institute of Technology, Cambridge, Mass., 1947. Paper, $8\frac{1}{2} \times 11$ in., 193 pp., diagrams, charts, tables, $2.50. This publication is a formulation of a servomechanism design procedure based primarily upon an analysis of the system response to sinusoidal inputs of various frequencies. The methods developed are based upon the characteristics of the servomechanism transfer function. Following the discussion of compensating functions, their physical realization is considered using several different types of circuits. Advantages and shortcomings of the various compensating devices are discussed.

CENTRIFUGAL AND AXIAL FLOW PUMPS, Theory, Design, and Application. By A. J. Stepanoff. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1948. Cloth, $5\frac{3}{4} \times 9\frac{1}{4}$ in., 428 pp., illus., diagrams, charts, tables, $7.50. The theory, design, and application of centrifugal, mixed-flow, and axial-flow pumps are covered from a practical viewpoint, with a wealth of descriptive sketches, analytical charts, and performance-characteristic diagrams. Included is a new and simple treatment of the impeller which applies equally well to centrifugal and axial-flow pumps. Numerous examples of modern pump designs and installations are given.

CORROSION HANDBOOK. Edited by H. H. Uhlig and sponsored by The Electrochemical Society, Inc., New York, N. Y. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1948. Cloth, $6 \times 9\frac{1}{4}$ in., 1188 pp., illus., diagrams, charts, tables, $12. This reference work provides a condensed summary of information covering all phases of corrosion, including within its scope a cross section of scientific data and industrial experience. The major emphasis is on corrosion prevention and the behavior of metals and alloys in various environments at both ordinary and extreme temperatures. Quantitative rather than qualitative data are considered. Current corrosion theory is covered as well as corrosion testing. More than one hundred authorities in the field contributed and a wealth of footnote references lead to further treatments of the subject matter.

GASTURBINENKRAFTWERKE. By L. Musil. Springer-Verlag, Vienna, Austria, 1947. Paper $5\frac{1}{4} \times 8$ in., 108 pp., diagrams, charts, tables, 12 Schw. fr. After a brief discussion of the restricted developmental possibilities of steam power, this small volume describes the various types of gas-turbine systems, covers the use of solid fuels for gas generation for the gas-turbine plant, and indicates what can be done in the matter of by-products such as tar and sulphur. The prospect of the use of gas-turbine plant for electrical utilities is kept in mind throughout.

JACOB INTEGRAPH INSTRUCTIONS AND TYPICAL PROBLEMS, by B. C. Jacob, 205 N. Mountain St., Bay City, Mich. Photo-offset by Polygraphic Company of America, New York, N. Y., 1947. Paper, $6 \times 8\frac{1}{4}$ in., 126 pp., diagrams, charts, tables. Apply to author. The Jacob Integraph, in one form is a small transparent triangle having ruled lines and small perforated holes so placed as to make it possible to perform graphically a variety of calculus problems in addition to arithmetical and analytical computations. Its most important use is to integrate and differentiate graphically curves of any shape. The Jacob Integraph provides a method by which engineers can use graphical calculus with second or more integrations or differentiations. It may be used with an ordinary T-square or triangle or in another form as an attachment on a universal drafting machine. The accompanying instruction book gives a detailed explanation: first, of the simple fundamental operations; and then, of more complex problems in mechanics and engineering, including a variety of practical applications such as determining bending moments and deflections in beams and shafts, impact or collision values, forces and accelerations, volumes of tanks, etc.

JET PROPULSION PROGRESS, the Development of Aircraft Gas Turbines. By L. E. Neville and N. F. Silsbee. McGraw-Hill Book Co., Inc., New York, N. Y., and London, England, 1948. Cloth, $6 \times 9\frac{1}{4}$ in., 232 pp., illus., diagrams, charts, tables, $3.50. Presenting the fundamentals of the gas turbine as applied to aircraft, this book outlines the development of such units in Germany, Great Britain, and the United States. The problems of heat-resistant alloy, special fuels for jet propulsion, and maintenance of jet engines are indicated briefly, as well as future developments and possible uses. Although a considerable amount of technical material has been included, elaborate calculations, engineering formulas, and highly technical discussions have been avoided. Included are a chronology of aircraft gas-turbine developments, a glossary of technical terms and abbreviations, and a comprehensive bibliography covering the period 1941 to March, 1947.

MECHANICAL FEEDERS. (Printing Theory and Practice No. 8.) By V. S. Ganderton. Sir Isaac Pitman & Sons, Ltd., London, England, 1946. Cloth, $5 \times 7\frac{1}{2}$ in., 207 pp., illus., diagrams, 4s6d. One of a series of books covering the entire printing industry, this small volume describes the construction and operation of the following types of automatic feeders: front-separation feeders, back-separation and friction feeders, stream feeders.

MODERN TIMBER DESIGN. By H. J. Hansen. Second edition. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1948. Cloth, $5\frac{3}{4} \times 9\frac{1}{4}$ in., 312 pp., illus., diagrams, charts, tables, $4.50. The properties of various species of wood, the factors affecting their structure, their assigned working stresses, and modern timber-design methods are covered with examples and formulas for use in design. Two new chapters appear in this revised edition, presenting the factors affecting the strength of wood, and a

fuller explanation of wood-testing methods. Material on the design of all types of joints, of glued laminated members, and of plywood is featured.

LA PHOTOÉLASTICITÉ. By A. Pirard. Dunod, Éditeur, Paris, France, 1947. Paper, 6 × 9½ in., 419 pp., illus., diagrams, charts, tables, 1550 fr. Following an extended discussion of the theory of elasticity, this text takes up the subject of photoelasticity from both the theoretical and practical points of view. Birefringence and polarization are discussed, materials and equipment for photoelastic examination are described in detail, and practical applications are demonstrated with examples of photoelastic studies.

PHOTOELASTICITY, Vol. 2. By M. M. Frocht. John Wiley & Sons, Inc., New York, N. Y.; Chapman & Hall, London, England, 1948. Cloth, 6 × 9¼ in., 505 pp., illus., diagrams, charts, tables, $10. This treatise on advanced principles and methods includes the following: Essential elements of the theory of elasticity; a critical examination of the influence of the physical constants on the state of stress in two dimensions; a broad survey of the methods for the determination of the sums of the principal stresses with special emphasis on the numerical solution of Laplace's Equations. It also presents the theory and technique of three-dimensional photoelasticity with applications to stress concentrations.

PROBLEMS ON APPLIED THERMODYNAMICS. By V. M. Faires, A. V. Brewer, and C. M. Simmang. Revised edition. The Macmillan Company, New York, N. Y., 1948. Paper, 6 × 9¼ in., 151 pp., diagrams, charts, tables, $1.70. These problems are designed especially for use with the authors' "Applied Thermodynamics," but may be combined with any text which uses the same terminology and emphasizes the general energy equation. Steam tables and other useful data are provided in an appendix. To suit the needs of individual instructors answers are given for only part of the more than 1400 problems included.

SPI HANDBOOK. Society of the Plastics Industry, Inc., New York, N. Y., 1947. Fabrikoid, 6 × 9¼ in., 451 pp., illus., diagrams, charts, tables, $7.50 to nonmembers, $4.50 to members. The results of six years of planning and four years of effort by 300 technicians in the plastics industry, this handbook covers the subjects of primary importance to good engineering of plastics. A classification of plastics molding materials is given. Molding processes, design of molded articles, cementing and assembling, testing, mold design, machining, and finishing are covered. Included also are standards for the design of inserts, for tolerances on molded plastic parts, and for laminated products.

STRENGTH OF MATERIALS. By J. Marin. The Macmillan Company, New York, N. Y., 1948. Cloth, 6 × 9½ in., 464 pp., diagrams, charts, tables, $4.75. Written as a text for a beginning college course, this book co-ordinates mechanical properties under various types of static stress, analysis of stresses, and design of simple machine and structural members. It is arranged in four parts: Part 1 deals with simple stresses; Part 2 with combined stresses; and Part 3 with statically indeterminate stresses. Special topics are considered in Part 4, and an appendix treats centroids and moments of inertia of plane areas. Tables of physical properties and design stresses for common engineering materials are included.

SYMPOSIUM ON LARGE-SCALE DIGITAL CALCULATING MACHINERY, Proceedings, jointly sponsored by the Navy Department, Bureau of Ordnance and Harvard University at the Computation Laboratory, January 7 to 10, 1947. Harvard University Press, Cambridge, Mass., 1948. Cloth, 7¾ × 10¾ in., 302 pp., illus., diagrams, charts, tables, $10. More than thirty papers, presented by specialists, are included in this symposium on the design, construction, operation, and application of this rapidly developing, recent type of mathematical tool. The papers are grouped by the separate session subjects: existing calculating machines; logic of large-scale calculating machinery; storage devices; numerical methods and suggested problems; sequencing, coding, and problem preparation; input and output devices; conclusions and discussion.

TABLES OF PROPERTIES OF GASES With Dissociation Theory and Its Applications. By E. W. Geyer and E. A. Bruges. Longmans, Green and Co., London, England, New York, N. Y., and Toronto, Canada, 1948. Cloth, 6 × 9¼ in., 102 pp., charts, tables, $3. This book contains tables on the thermal properties of oxygen, nitrogen, hydrogen, water vapor, carbon monoxide and dioxide, ethylene, octane, and benzene. The tables run from 400 to 5400 F abs. for the most part, with a few going higher. Linear interpolation for intermediate temperatures is possible. The derivation of the tables, a modern approach to the theory of dissociation, and directions for the use of the tables are included.

Zurich, Switzerland, Eidgenössische Technische Hochschule, Institut für Flugzeugstatik und Flugzeugbau, Mitteilung Nr. 1, TORSIONSSTEIFIGKEIT IM FLUGZEUGBAU VERWENDETER SYSTEME, by I. Nural. Verlag A. G. Gebr. Leemann & Co., Zurich, Switzerland, 1946. Paper, 6½ × 9½ in., 93 pp., illus., diagrams, charts, tables. This is a study of a wing model which is constructed of two box beams on either side of an open central space where the fuselage would normally be. The first part deals with the determination of the fundamental relationships, in the wing model, between the bending resistance of the spar in the "open" central part of the wing and the resistances to torsion and curvature of the "box beams" at both ends. This is done in order to obtain the total torsional resistance under symmetrical and continuous torsional load. The latter case is investigated with and without the influence of the fuselage. In the second part, practical examples are investigated mathematically and experimentally.

ASME BOILER CODE

Interpretations

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Anyone desiring information on the application of the Code may communicate with the Committee Secretary, ASME, 29 West 39th St., New York 18, N. Y.

The procedure of the Committee in handling the Cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are then sent by the Secretary of the Committee to all members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and is passed upon at a regular meeting.

This interpretation is later submitted to the Council of The American Society of Mechanical Engineers for approval after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Following is a record of the interpretation of this Committee formulated at the meeting of April 2, 1948, and approved by the Council on May 3, 1948.

CASE NO. 732

(*Annulled*)

CASE NO. 940

(*Annulled*)

CASE NO. 1068

(*Special Ruling*)

Inquiry: Is it permissible to use plates of open-hearth process steel which meet ASTM Specifications A 7–46 Steel for Bridges and Buildings, A 113–46 for Structural Steel for Locomotives and Cars, and A 283–46T for Carbon Steel Plates of Structural Quality, in the construction of pressure vessels?

Reply: It is the opinion of the Committee that these materials, except as noted below, are limited to use for unstayed flat plates used as covers, tube sheets, blind flanges and on which no strength welding is to be applied and for use within the temperature limits and at the stresses given below:

	—20 to 650 F
A 7—Plates Only	11,000
A 133 Plates Only	9,600
A 283 Grade A	9,000
A 283 Grade B	10,000
A 283 Grade C	11,000
A 283 Grade D	11,000

A factor of 1.25 may be applied to these stresses under Pars. U-200 and U-201.

These materials may also be used for Par. U-70 vessels having a shell thickness of ¼ in. or less, at the reduced stresses provided in that paragraph.

ASME NEWS

And Notes on Other Engineering Societies

COMPILED AND EDITED BY A. F. BOCHENEK

Varied Technical and Social Program Characterized ASME 1948 Semi-Annual Meeting Held in Milwaukee, Wis., May 30–June 5

A VARIED technical program featuring symposiums on anti-icing, steam contamination, design and standardization of splines, deterioration in quality of available coal, and a review of early work in pulverized-coal burning attracted more than 1500 engineers and industrialists to the 1948 Semi-Annual Meeting of The American Society of Mechanical Engineers held at the Hotel Schroeder, Milwaukee, Wis., May 30–June 5, 1948.

Adding to the pleasure of the meeting was the festive spirit of the centennial celebrations of the State of Wisconsin, and a social program consisting of a stag smoker, a Dutch-treat night-club tour, and a rathskeller party. These informal events, coupled with the more formal luncheons and dinners, afforded plenty of time for stimulating contacts among old and new friends.

An industrial exposition, consisting of 40 exhibit areas, gave delegates a convenient bird's-eye view of industrial Wisconsin, while a well-planned program of inspection trips added diversity and an opportunity to see at firsthand some of the nation's largest industrial plants operating at full capacity.

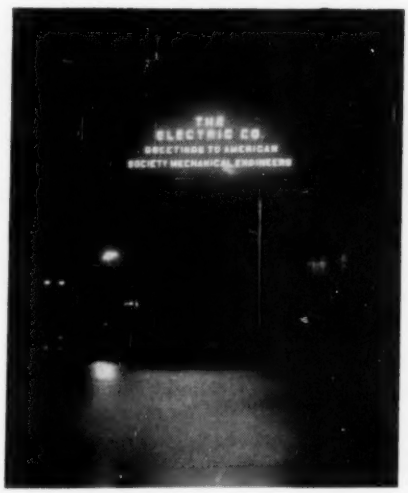
While members were otherwise engaged in Society affairs, their wives were enjoying the cultural life and treasures of Milwaukee.

On Sunday, May 30, ASME officers, Regional delegates, and committeemen were at work conducting the essential business of the Society. While the Regional Delegates Conference was considering the suggestions of the Sections in one room, the Executive Committee was meeting in another. The Council met in the afternoon. Throughout the week, against the background of technical discussions and social events, program-making agencies and administrative committees evaluated the work of the Society and plotted the course of future activities.

29 Technical Sessions

The technical program, consisting of 29 sessions sponsored by 20 professional divisions and committees, covered a variety of subjects in the field of machine design, gas-turbine and steam power, management, applied mechanics, hydraulics, and others. Since all papers for which manuscripts have been received will be published in full or in digest form in several issues of MECHANICAL ENGINEERING, no attempt has been made to present a comprehensive account of the many interesting sessions. For convenience of members who wish to purchase preprints, a list of papers currently available at headquarters is given on page 646. Some of the program high lights follow.

A feature of the Machine Design Division program which consisted of five sessions was a symposium on the design and standardization of splines. This consisted of four papers on



ELECTRIC LIGHTS GREET ASME AT SEMI-ANNUAL MEETING IN MILWAUKEE, WIS.

the subject by representatives of the machine-tool industry. Other papers sponsored by the division gave a description of a new freight-car coupler (48—SA-4); a discussion of savings possible by modern projection-welding techniques (48—SA-17); a new approach to the design of dynamically loaded compression and extension springs (48—SA-23); and cheaper methods of manufacturing by designing for induction heating (48—SA-32).

Contributions in the field of the gas turbine included a study of economies possible by operating a gas turbine in combination with a waste-heat boiler. This paper was published

THE ASME 1948 SEMI-ANNUAL BANQUET, HELD AT THE SCHROEDER HOTEL, MILWAUKEE, WIS., JUNE 2, 1948

(Members and guests heard William A. Lydgate, editor of the Gallup Poll, discuss what the American people think about Russia and how they evaluate the current domestic political situation.)

July News High Lights

MECHANICAL engineers were told at the ASME Semi-Annual Meeting in Milwaukee, Wis., that they had much to contribute to the development of atomic-energy research. The laboratories are looking to them for remote-control devices upon which advancements in this new field depend (643).

The principles of good management are not being generally applied in industry because of union antipathy for incentive methods, according to C. C. James, who addressed the Management Luncheon in Milwaukee. Only an increase in production can forestall a serious depression. This, he said, was a job for the engineer rather than the politician or the economist (644).

Development of new sources of mechanical power in the face of tremendous power demand and shrinking supplies of petroleum and natural gas was the challenge facing the engineer, Julius A. Krug told the Semi-Annual Meeting delegates. A national Energy Policy was needed to plan use of electric-power resources (644).

Do not overlook vacation possibilities of the ASME Fall Meeting Tour which will take in many of the western national parks on the way to and from the ASME Fall Meeting to be held in Portland, Ore., Sept. 7–9, 1948 (649).

The new premier of China is an honorary member of the Society (647).

The 1948 Mechanical Engineering Conference sponsored annually by the ASME Pittsburgh Section was devoted to advances in the metalworking industries and management problems involved (650).

The ASME is sole sponsor of a new standard on industrial power trucks. The Committee chosen to draft the standard held its organizational meeting in May, 1948 (650).

Comments from engineers in industry are being sought by the ASME Boiler Feedwater Committee on its revised rules recommended for chemical conditioning of boiler feedwater. The revised rules were published on pages 557–560 of the June issue of MECHANICAL ENGINEERING (648).

POWER(III) SESSION ON THURSDAY MORNING ON STEAM-TURBINE DESIGN AND REGULATION

(Twenty-nine technical sessions, sponsored by 20 professional divisions and committees and featuring five symposiums, provided rich fare for the delegates.)

in the June issue of MECHANICAL ENGINEERING. Other papers discussed construction of a gas turbine for a locomotive power plant and the comparison between Anglo-American and Swiss methods of computation and design of axial compressors.

In the field of steam power a symposium on steam contamination sponsored by the Power Division stimulated much discussion. Four representatives of public utilities made the following contributions: (1) A method of deposit removal by washing high-pressure-turbine blades with saturated steam and low-pressure blades with caustic-soda solution (48—SA-24); (2) a method based on 22 years of operating experience of preventing scale deposits by using evaporated makeup (48—SA-25); (3) a method of reducing deposits by internal treatment with magnesium chloride in absence of phosphate (48—SA-26); and (4) an account of high-pressure-turbine deposit experience including suggestions for improvement in the caustic-soda washing technique.

Among the topics discussed in the field of management were human relations in industry; a study of management policies of successful corporations; a review of ten months of experience with the Taft-Hartley Act; the significance of break points; and the technique of establishing production standards without use of a stop watch. In another paper the division was told that Europe is looking to America for technological assistance.

A highly successful session on anti-icing was sponsored jointly by the Aviation and Heat Transfer Divisions. Eight papers were presented on the subject by engineers representing aeronautical laboratories and airline operators in addition to four discussers.

A fuels symposium on the effect of trends in coal quality and availability on boiler design was held Friday morning. Also sponsored by the Fuels Division were three papers covering the early work in pulverized coal and high-pressure steam generation carried on at Milwaukee, Wis.

Digests of nine of the Semi-Annual Meeting papers will be found in the ASME Technical Digests of this issue. Three others were published in the June issue.

Two Films Shown

Recognition by the engineering profession of the need for action in the defense of private enterprise and personal freedom was indicated by one of the first sessions of the meeting. More than 100 members and guests attended a program at which two educational-type films were shown, both using the same technique, but each conveying contradictory messages. The first, "Deadline for Action" was prepared at the CIO United Electrical Workers and conveyed by misinterpretation of fact and half-truths, the idea that the United States was controlled by eight financial interests, classed vaguely as "big business." The film gave force to the warning expressed by David Larkin, Fellow ASME, when he said, prior to the showing of the film, "it behooves the engineer to take an active interest in governmental affairs," if he cherishes individual freedom and believes that private initiative is possible only under a truly democratic government. The CIO message, prepared at great expense, urged "the people" to take over the country via the ballot box in November.

The second film, "Crossroads for America," using the same facts and technique, told the other half of the story. It pointed out that while there is much to be improved in America, improvement can best come through free enterprise and personal freedom. The film produced by the Research Institute of America showed that "big business" was in effect "the people" because one half of the money behind American enterprise was supplied by 20 million investors.

Earlier in the program William H. Larkin, Mem. ASME, and president of the New York State Society of Professional Engineers, discussed the economics and history of professional licensure. A professional engineering license has economic value, he said, because industry was beginning to require such a license as a prerequisite for promotion beyond a certain level.

Mechanical-Engineering Achievement

Official welcome of the City of Milwaukee and the ASME Milwaukee Section was extended to 200 members and guests who attended the Nuclear Energy Luncheon, Tuesday, June 1, which was the first social event of the meeting.

Theodore Wetzel, general chairman of the meeting, introduced the chairmen of the various local committees. George A. Parkinson, director of the extension division of the University of Wisconsin, was toastmaster. He introduced in turn eminent Milwaukee engineers serving on the Technical Honorary Committee, E. G. Bailey, president ASME, T. S. McEwan, vice-president, ASME Region VI, the Hon. Frank Zeidler, Mayor of Milwaukee, and others at the speakers' table.

"Mechanical-engineering achievement" was

the key to Milwaukee's fame, according to Mayor Zeidler. A good harbor contributed to the city's early success, but it was not until Milwaukee cultivated "heavy industry and imported skilled mechanics from Europe" that the city surpassed its neighbors in prosperity. Today, Mayor Zeidler said, with 50 per cent of its people engaged in manufacturing, Milwaukee's fame is due principally to the "skill of its mechanical engineers."

President Bailey complimented Milwaukee for its "good judgment in keeping its industry diversified" and for providing the friendly environment which has made it possible for all the industries represented by the 21 professional divisions of the ASME to prosper under its jurisdiction. President Bailey called attention to Milwaukee as the "home of pulverized coal as applied to the central station."

Remote-Control Engineering

Following the welcome ceremonies, O. C. Simpson of the Argonne National Laboratory, Chicago, Ill., spoke on "Some Engineering Problems of Peacetime Atomic Energy Research." Mechanical engineers have much to contribute, he said, to the solution of unprecedented mechanical problems currently hampering atomic research.

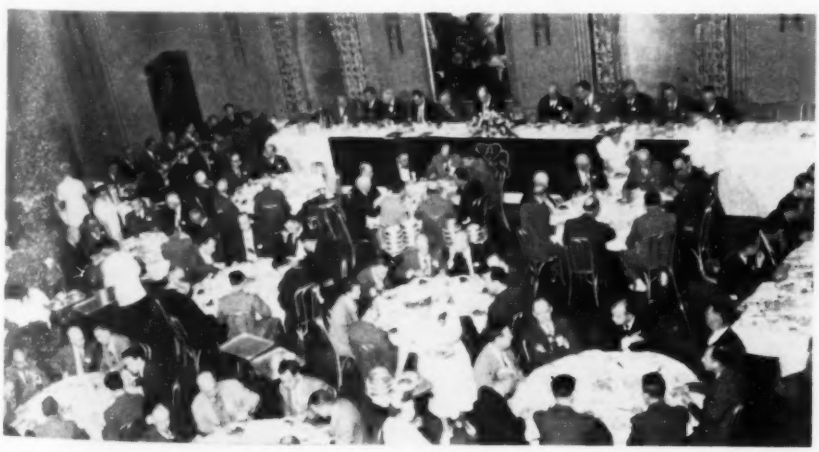
Because of the deadly effects of radiation, which make necessary heavy shielding of virtually all research apparatus, remote-control engineering, Dr. Simpson said "may be the most important single field in the future development of atomic energy." He emphasized that "there is hardly any research today involving nuclear science which does not involve remote-control operations to some extent" and that future developments probably would include an "automaton" with apparatus to carry on operations in an airtight structure heavily shielded against the deadly radiation.

Dr. Simpson showed several slides, recently declassified, which illustrated ingenious remote-control mechanisms used in atomic-energy research. These included a small over-the-wall hand manipulator with which "hot" specimens and delicate laboratory apparatus could be handled from a position protected by a heavy radiation shield. Another tool was an over-the-wall periscope equipped with a viewer with a rotation of 360 degrees which enabled the research worker to view apparatus from a protected position.

While these devices were useful they were not adequate for the job ahead, he said. The speed with which nuclear research advances in the future will depend largely on the speed in the development of remote-control engineering. More engineering talent with atomic research know-how is needed, he warned, if this country is to maintain its leadership.

E. A. UEHLING, 99-YEAR-OLD MEMBER, RECALLS EARLY DAYS OF THE SOCIETY

(*Left to right:* Mr. Uehling, Theodore Wetzel, O. C. Simpson, E. G. Bailey, president ASME, and George A. Parkinson. Mr. Uehling invented the first pig-iron casting machine, one of the early pyrometers, and is well known as a manufacturer of a CO_2 recorder. He was honored at the meeting by the award of a certificate noting his 65-year membership in the Society.)



NUCLEAR ENERGY GENERAL LUNCHEON AT THE ASME SEMI-ANNUAL MEETING, JUNE 1, MILWAUKEE, WIS.

(Remote-control engineering was the field of atomic research in which mechanical engineers can make significant contributions, Dr. O. C. Simpson of the Argonne National Laboratory, told the guests.)

Other mechanical problems discussed were: Design and construction of a more versatile cyclotron; better design of shielding materials for construction of temporary shielding walls; cheaper and more versatile apparatus for isotopic separation; air conditioning and ventilation of research laboratories; and disposal of atomic wastes.

Three Awards Presented

The banquet held on Wednesday, June 2, was attended by more than 500 engineers and guests representing the mechanical-engineering industries of Milwaukee, and was the social high light of the Meeting.

Joseph B. Armitage, director at large, ASME, opened the after-dinner program by introducing 24 honored guests at the speakers' table. Francis J. Trecker, Jun. ASME, president, Kearney and Trecker Corporation, Milwaukee, Wis., was toastmaster.

President Bailey, after expressing the appreciation of the ASME for the warm welcome and hospitality of the Milwaukee Section and the City of Milwaukee, presented a certificate of appreciation to Dr. Frank Martinuzzi for his services as 1948 ASME lecturer. Dr. Martinuzzi, who is director of research, coordination on gas turbines, National Research Council of Rome, Italy, has been making a comparative study of American and continental gas-turbine design practices and has lectured on the subject before many ASME sections. Mr. Bailey then presented a fifty-year membership pin to Frederick W. Walker, vice-president, Northwestern Mutual Life Insurance Company, Milwaukee, Wis.

The next award was announced as one of the rarest in ASME. It was a certificate of 65 years membership in the Society to E. A. Uehling, retired inventor and engineer of Milwaukee, who joined the Society in 1883 and who

would, in another year, become a centenarian. While not at the banquet, Mr. Uehling attended the Management Luncheon.

President Bailey recalled, as a young man, his admiration for Mr. Uehling who, at the turn of the century, already had earned a national reputation as the inventor of the first pig-iron casting machine, the first recording pyrometer in the United States, and as the manufacturer of one of the early CO_2 recorders.

1948–1949 Nominations

Before introducing the main speaker, Mr. Trecker called on the secretary to announce nominations of the 1948–1949 officers of the Society. They are: President, James M. Todd, consulting engineer, New Orleans, La.; vice-president Region II (renomination), A. R. Mumford, development engineer, Combustion Engineering Company, New York, N. Y.; vice-president Region IV, A. Roberts, Jr., chief engineer, Lynchburg Foundry Company, Lynchburg, Va.; vice-president Region VI, Forrest Nagler, chief mechanical engineer, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.; vice-president Region VIII, Carl J. Eckhardt, Jr., professor of mechanical engineering, The University of Texas, Austin, Texas; directors at large, four years, J. A. Keeth, manager power production, Kansas City Power and Light Company, Kansas City, Mo., and Ralph A. Sherman, supervisor, fuels division, Battelle Memorial Institute, Columbus, Ohio.

Photographs and biographical sketches of nominees will be published in the August issue of MECHANICAL ENGINEERING.

American Public Opinion

What American people were thinking on domestic and international political questions and how they felt on many less vital but important human matters, was reviewed by William A. Lydgate, editor of the Gallup Poll who spoke on "What America Thinks Today." Mr. Lydgate said that the accuracy of polls was not based on size but on the homogeneity or accuracy of the representative sample. The Gallup Poll sampling ranges, he said, from 3 to 60 thousand carefully selected with respect to age, sex, size of community, and other factors which influence opinion. A sampling of national opinion could be made in four days and the results were regularly disseminated to 130 daily newspapers which underwrite the Poll, Mr. Lydgate said.

Referring to American opinion on Russia, he said the Americans were overwhelmingly for a tough policy because they believed that Russia was: (1) Trying to dominate the world; (2) trying to exterminate Christianity; (3) acting in an unfriendly manner in not permitting American travel in Russia; (4) seizing satellite countries by illegal means; and (5) wrecking the United Nations by not co-operating.

Commenting on the pending political campaigns, Mr. Lydgate said that at the moment a Republican victory seemed likely, but that the choice of a wrong nominee or a sense of easy victory on the part of the Republican party could spell defeat. While the Republicans have a great friend in Henry Wallace, the party must defeat not only Harry S. Truman, but a man of tremendous prestige who would not even appear on the ballot. That man was General George Marshall. Many voters, he said, might be reluctant to vote the Republican ticket, should it develop that such a vote would be against Marshall.

After the banquet, many members enjoyed a "Dutch treat" tour of some of the night clubs of the city.

AT THE UNIVERSITY OF WISCONSIN DINNER, FRIDAY, JUNE 4, 1948

(*Background, left to right:* Ernest Hartford, Mrs. Julius A. Krug, Theodore Wetzel, Mrs. E. G. Bailey. *Foreground:* Mrs. Parkinson and George A. Parkinson. As main speaker, Secretary Julius A. Krug called attention to the dwindling supplies of petroleum and natural gas and called on engineers to face the problem of new sources of mechanical power. A national energy policy was needed to plan effective use of available power sources, he said.)

Job for the Engineering Profession

If the engineering profession can induce labor and management to apply the principles of scientific management first stated more than 40 years ago by one of its own members, Frederick W. Taylor, it may be able to forestall economic depression and bring to its senses a world currently "living in a fool's paradise."

This was the message of C. C. James, management counselor, New York, N. Y., who was the main speaker at the Management General Luncheon on Wednesday, June 2. His subject was "The Role of Scientific Management in World Recovery."

Referring to the destruction abroad, Mr. James said that America too has lost wealth, although most people, deluded by the abundance of money, did not recognize that fact. The recovery of real wealth, which was destroyed by the war or never created because of misdirected effort, could be achieved only by "intelligently directed hard work." Quoting Adam Smith, he said "good judgment, in addition to capital and labor, must be employed in the creation of wealth."

Defining good management as good judgment, Mr. James distinguished between the tools of management, for example, methods studies, job evaluation, and costs standards, and the act of managing, which is the application of these tools.

Taylor's Principles

Although Taylor's principles of good management have been known for a long time, they were not effectively contributing to the recovery of the world because of restrictions on production imposed by labor unions.

Mr. James outlined Taylor's principles as: (1) Codification by management of traditional knowledge of the best way of accomplishing tasks; (2) scientific selection and progressive development of workers, that is, fitting the man to the job; (3) helping the workers to learn the best way to do their work; and (4) servicing the worker by planning his work, providing tools and equipment, moving materials to him, and providing for his physical comfort on the job.

Labor's antipathy for incentive methods introduced by industry to break down restrictive practices was based on fear expressed by the well-known union slogan, "Sweat Today and Starve Tomorrow." Memories of the 1930's, when the workers were laid off because pipe lines were full and couldn't flow because the purchasing power of the market was lowered by loss of income of the workers, were still vivid, Mr. James said.

What was needed was a new spirit in the labor-management relationship which recognized the value of free enterprise and fair play on one hand, and the importance of job security and class consciousness on the other. Recent contracts have given evidence of the emergence of this new spirit.

But if another economic disaster were to be prevented, the principles of scientific management must be brought into play. Initiative in this field is beyond the talents of politicians or economists. Perhaps this was a task for the engineer, Mr. James concluded.

National Energy Problems

Julius A. Krug, Secretary of the Interior, was the main speaker at the University of Wisconsin dinner held Friday, June 4. Speaking on "National Energy Problems," Secretary Krug warned that the nation faces a critical situation with respect to such energy sources as petroleum and natural gas. There is an eminent danger of electric-power shortage today, he said, because the power industry does not have a proper safety factor with regard to reserve capacity. What is needed is a national energy policy to plan the use and development of mechanical power. The government should

finance private industry to increase capacity, and in those fields where private industry is not ready to go ahead the Government should do so on its own. An adequate supply of electric power is the responsibility of both private and public finance. In the search for new and better resources of power, the engineer finds his best challenge, he concluded.

Secretary Krug's talk was preceded by a concert by the Pro Arte Quartette of the University of Wisconsin and the presentation of honors to Wisconsin engineers. Alex D. Bailey, Fellow ASME and past-president ASME, was toastmaster.

Fun in Milwaukee

There was more at the Semi-Annual Meeting than serious sessions, committee meetings, and formal luncheons. On Tuesday evening 225 delegates joined in a stag smoker to enjoy a buffet dinner, a six-act show, a ten-piece orchestra, some free beer, and the kind of singing that comes from deep down. The same kind of good fellowship was evident at the rathskeller party on Thursday evening. As guests of the Pabst Brewing Company, the delegates gave the bottling division of the company a circumspective glance, judged the operations good, and hastened back to where music and singing and good food were creating an impression long to be cherished.

Inspection Trips Popular

The plant-inspection program had many a delegate tossing a coin to make the choice between a technical session about to be called to order and the call reverberating down the corridors announcing that the bus was loading for one of the ten inspection trips planned during the week. Large parties took advantage of the opportunity to observe operations and inspect facilities of the following Milwaukee plants: Kearney and Trecker Corporation, Nordberg Manufacturing Company, The Falk Corporation, A. O. Smith Corporation, Allis-Chalmers Manufacturing Company, Pabst Brewing Company, Milwaukee Municipal Sewage Disposal Plant, Milwaukee Road Shops. Trips were also made to the Port Washington Power Plant and to the USCG *Mackinaw* and the NR PC808.

MEMBERS INSPECTING GEARS AND SPLINES AT ALLIS-CHALMERS MANUFACTURING COMPANY DURING ONE OF THE PLANT-INSPECTION TOURS

Engineering Exposition

In the heart of the headquarters hotel meeting area two large rooms were devoted to the Industrial Wisconsin's engineering exposition, where some of the notable engineering products of Wisconsin were on display. The exposition, sponsored by the ASME Milwaukee Section, added a new note to an ASME national meeting. Between events on the program, the exposition served as a center of interest where delegates could profitably spend a few leisurely moments enjoying the displays of products.

Committees

Appreciation and thanks are extended to the members of the committees of the ASME Milwaukee Section who worked hard to plan and organize the 1948 Semi-Annual Meeting. The chairmen and committee members follow:

Finance Committee: George Miniberger, chairman; W. C. Lindemann, Sr., assistant chairman; R. J. Fobian, B. V. E. Nordberg, H. E. Rumpf, M. E. Ruess, Bartholomew Pinter, and H. A. Schwantes.

Inspection Trips Committee: Alfred Hoppe, chairman; Robert Cramer, assistant chairman; Robert Cunningham, Erhardt Koerper, Joseph Drinka, Harry Gute, Philip Isme, and Vernon Green.

Exhibits Committee: Donald Maulin, chairman; Victor Johnson, assistant chairman; Edmund Lippmann, Theodore Angel, Adolph Hilgert, Frank White, John Kline, James Brower, and Francis White.

Program Committee: Alfred Schmidt, chairman; Joseph Roubik, assistant chairman; George Sirotkin, Norman Jacobsen, William Tucker, and John Bunce.

Entertainment Committee: Robert Miller, chairman; James Mulligan, assistant chairman; William Rheingans, Durward Stevens, Michael Maletz, and P. A. White.

Banquet Committee: J. Verne Resek, chairman; James Van Vleet, assistant chairman; Harry Emmert, Jr., Troels Warming, Russell Smith, Marcus Judd, and Frank Roberts.

Publicity Committee: A. Warren Colwell, chairman; Clifford Homes, assistant chairman; Gilbert Dittl, Henry Roesler, Peter Woods, and Alfred Meeg.

Service Committee: George Suchy, chairman; Julius Olsen, assistant chairman; F. Warren Weithofer, Robert Losse, and Ellis Hansen.

Reception Committee: Ernest Szekely, chairman; Forrest Nagler, assistant chairman; W. D. Bliss, W. Crawford, Harold Heywood, W. D. O'Connor, Hugh S. Brown, Emil Grieshaber, C. F. John, and J. E. Schoen.

Program Co-Ordinating Subcommittee: A. O. Schmidt, chairman; J. P. Bunce, assistant coordinating chairman; A. G. Hoppe, Robert Miller, J. V. Resek, Ernest Szekely, Eric Laabs, Donald Naulin, and G. F. Suchy.

Woman's Auxiliary Convention Committee: Mrs. A. H. Ehlinger, chairman; Mrs. L. H. Stark, Woman's Auxiliary to the ASME; Mrs. S. Gates, Mrs. W. C. Lindemann, Mrs. T. A. Wetzel, Mrs. G. C. Jett, and Mrs. B. V. E. Nordberg.

Ladies Program Committee: Eric Laabs, chairman; L. H. Stark, assistant chairman; W. A. Alexandroff, James Hunt, and Arnold Ehlinger.

Ladies Reception Committee: Mrs. W. D. O'Connor, chairman; Mrs. F. L. Dornbrook and Mrs. E. Greishaber.

Ladies Registration Committee: Mrs. Hugh Brown, chairman; Mrs. R. Cunningham, Mrs. W. C. Lindemann, and Mrs. S. Gates.

Ladies Transportation Committee: Mrs. H. Gute, chairman; Mrs. R. Cunningham, Mrs. F. W. Weithofer, and Mrs. F. Nagler.

ASME BOOTH AT INDUSTRIAL WISCONSIN'S ENGINEERING EXPOSITION WAS A PART OF THE ASME SEMI-ANNUAL MEETING

(Semi-Annual Meeting preprints are shown on the extreme right. The central display contains some of the regular and special ASME publications. Members came to this booth to purchase preprints of papers presented at technical sessions which they attended.)

H. A. Hopf Knighted

H. A. HOPF, Mem. ASME, was made a Knight of the Royal Order of the Northern Star, by sanction of the King of Sweden at the annual dinner of the Swedish Management Association, held in Stockholm, Sweden, March 31, 1948.

ASME 1948 Semi-Annual Meeting Preprints

Pamphlet copies of the following ASME Semi-Annual Meeting papers are available from ASME Publication-Sales Department, 29 West 39th St., New York 18, N. Y.

Paper No.	*Title and Author*
	Applied Mechanics
48—SA-1	Centrifugal and Thermal Stresses in Rotating Disks, by W. R. LEOPOLD, JR.
48—SA-2	The Manifold Problem, by J. D. KELLER
48—SA-3	Gyroscopic Effects on the Critical Speeds of Flexible Rotors, by R. B. GREEN
	Aviation
48—SA-35	Icing Research—Accomplishments During the Past Winter, by RALPH J. HAWN
48—SA-36	Some Phases of Thermal Anti-Icing Systems, by R. M. POTTER
48—SA-37	Determination of Heat Requirements for Thermal Anti-Icing Determined by Tests Conducted at the Mt. Washington Laboratory, by T. P. KOEBEL
48—SA-38	What Is an Optimum Anti-Icing Design? by ROBERT L. BERNER and T. H. GRIEGER
48—SA-39	Service Experience With the Martin 202 Heat Anti-Icing System, by T. E. COOPER
48—SA-40	Heat Anti-Icing for the Airlines, by DAVID NORTH
48—SA-41	Icing Flight Tests of the Lockheed P2V, by R. L. THOREN
	Fuels
48—SA-7	Fuel Performance at Port Washington Station, by W. A. POLLOCK
	Gas-Turbine Power
48—SA-13	The Gas Turbine With a Waste-Heat Boiler, by G. R. FUSNER (Published in June MECHANICAL ENGINEERING)
	Heat Transfer
48—SA-11	An Extension of Two-Stream Heat-Exchanger Theory to Include the Effect of Longitudinal Conduction, by P. R. TRUMPLER
48—SA-16	Combustion Studies Using Golay Photothermal Detector With an Infrared Monochromator, by JOHN T. AGNEW
48—SA-27	Thermal Contact Resistance of Laminated and Machined Joints by A. W. BRUNOT and FLORENCE F. BUCKLAND
48—SA-43	Thermal Resistance Measurements of Joints Formed Between Stationary Metal Surfaces, by N. D. WEILLS and E. A. RYDER
	Hydraulic
48—SA-14	Performance Criteria for Positive-Displacement Pumps and Fluid Motors, by WARREN E. WILSON
48—SA-15	Design of Vaned Turns for a Large Water Tunnel, by J. M. ROBERTSON and A. J. TURCHETTI
48—SA-30	Cavitation Characteristics and Infinite Aspect Ratio Characteristics of a Hydrofoil Section, by JAMES W. DAILY
	Industrial Instruments and Regulators
48—SA-8	Diagnosing Engine Troubles in Flight, by JAMES W. WHEELER
48—SA-12	A Remote-Indicating Pressure Gage for Aircraft, by R. G. JEWELL
48—SA-29	Thermocouple Pyrometers for Gas Turbines, by E. F. FIOCK and A. I. DAHL
	Management
48—SA-50	A Pattern for Top Executive Action, by WILLIAM S. FORD
	Machine Design
48—SA-4	The Association of American Railroads Standard Car Coupler, by HUBERT L. SPENCE
48—SA-5	Broach Requirements for Spline Shafts and Fittings, by HARRY H. GOTBERG (To be published in MECHANICAL ENGINEERING)
48—SA-17	Modern Projection Welding, by ROBERT A. REICH
48—SA-18	Kinematic Considerations of Several Intermittent Variable-Speed Mechanisms, by G. J. TALBOURDET
48—SA-19	Hobs for Spline Shafts, by ANTHONY F. ZAMIS
48—SA-20	Involute-Spline Experience, by CHARLES H. STANARD
48—SA-21	Straight-Sided Splines, by J. B. ARMITAGE
48—SA-22	The Importance of Cores in Die-Casting Design, by C. R. MAXON
48—SA-23	A New Approach to the Design of Dynamically Loaded Compression and Extension Springs, by C. I. JOHNSON
48—SA-31	Transparent Models for the Demonstration and Study of Lubrication Phenomena, by JOHN BOYD (Published in July MECHANICAL ENGINEERING)
48—SA-32	Designing for High-Frequency Induction Hardening, by J. T. TEMIN
48—SA-33	Design and Manufacture for Profit, by H. B. OSBORN (To be published in MECHANICAL ENGINEERING)
	Metal Cutting
48—SA-9	An Evaluation of Cylindrical Grinding Performance, by R. E. MCKEE, R. S. MOORE, and O. W. BOSTON
48—SA-42	Theory and Practice of the Crush-Dressing Operation on Grinding Wheels, by E. C. HELFRICH
48—SA-10	Distribution of Heat Generated in Drilling, by A. O. SCHMIDT and J. R. ROUBIK
	Power
48—SA-6	High-Pressure-Turbine Deposit Experience, by W. L. WEBB
48—SA-25	Prevention of Turbine-Blade Deposits, by G. C. DANIELS
48—SA-24	Turbine-Blade Deposit—Burlington Generating Station, by W. E. KARG
48—SA-26	Reduction of Turbine and Superheater Deposits by Internal Treatment With Magnesium Chloride in Absence of Phosphate, by W. A. POLLOCK and F. H. LONG
48—SA-28	Design of Main Cylinder Joints in Steam Turbines, by E. M. GOLONKA
48—SA-34	Low Silica Content of Boiler Water Minimizes Turbine Silica Deposits, by J. N. EWART
48—SA-44	Steam-Turbine Governor Regulation, by C. E. KENNY, G. E. SCOTT, JR., and C. L. RINGLE
48—SA-49	Research Program on Steam Contamination and Turbine-Blade Deposits in High-Pressure Power-Plant Operation at the Armour Research Foundation, by H. E. ROBISON
	Railroad
48—SA-45	Thermal Environment of Railroad Passenger Cars, by K. A. BROWNE and S. G. GUINS
48—SA-46	Visual Passenger Comfort, by BROOKS STEVENS
48—SA-47	Decibel Level, by W. A. JACK
48—SA-48	Truck Riding Comfort, by K. F. NYSTROM

Use Coupon Books for Ordering ASME Papers

TO facilitate the ordering of preprints and reprints of ASME papers, Coupon Books are available to members at $2 for 10 coupons; $4 to nonmembers. Each coupon will purchase one copy of any preprint.

Scientist Confirmed Premier of China

WONG WEN-HAO, Hon. Mem. ASME, was recently confirmed premier of China. A noted geologist and chairman of the National Resources Commission, Dr. Wong was appointed by President Chiang Kai-Shek after two leading candidates rejected the job. Regarded primarily as a scholar, technician, and administrator, he is one of China's most respected public servants.

Born in Chekiang Province, Dr. Wong received a doctor of science degree from the University of Louvain, Belgium, taught at Tsinghua University, headed the National Geological Survey for sixteen years, and has written three standard works on the geology of China.

Since 1935, Dr. Wong Wen-Hao has held government posts as secretary of the Executive Yuan, minister of economic affairs, chairman of the War Production Board, vice-premier and chairman, with the rank of cabinet minister, of the National Resources Commission, which operates state-controlled heavy industry.

Policies on ASME Budget for 1948–1949

THE following statement of policies with the schedule of income and expense constitutes the Budget for 1948–1949.

1 A continuous effort will be made to collect dues by regular monthly billings. Quarterly payments will be accepted.

2 No appropriation shall be made by Council without first referring back to the Finance Committee for recommendation. When a liability is assumed the means for paying for it shall be provided in advance.

3 No new activity shall be undertaken without definitely showing that the funds required to support it will be available without decreasing the appropriations for existing essential activities, giving the consideration to the administrative expense that may be involved. When a new activity is authorized if the additional funds to support it are not directly available from the unappropriated income, Council shall say what activity shall be curtailed or suppressed to permit transference of the fund required to support the new activity. If the budget of expenses is to be reduced, the Council shall say what activity shall be curtailed or suppressed.

4 The Society shall hold four general meetings with expense chargeable to the 1948–1949 budget. A fee of $5 shall be charged to nonmembers for admission to general or technical sessions at the four National Meetings of the Society. The amount of the fee shall be the same for attendance at one or all of the sessions at a meeting. If a nonmember is the author of a paper presented at a meeting or if he has been formally invited to discuss a paper, he shall be exempt from payment of the registration fee for that meeting. Nonengineer members of the immediate family of a member shall also be exempt from payment of the registration fee.

5 Council meetings shall be held at the place and time of the Annual and Semi-Annual Meetings in 1949. Council representation within the budget shall be provided for the other national meetings.

6 Within the allowance of the budget, Vice-Presidents shall be expected to visit Sections and Student Branches and attend

COMBINED ANALYSIS OF EXPENDITURE BUDGET 1948–1949

	Under Committee Supervision			Printing and distribution	Office expense	Total
	Joint bodies	Members travel	Others			
PUBLICATIONS, STANDARDS, CODES AND RESEARCH						($503,910)
1 MECHANICAL ENGINEERING, text pages (excluding student copies)				$ 55,000	$ 27,250	82,250
2 MECHANICAL ENGINEERING, advertising pages (excluding student copies				66,100	61,138	127,238
3 Transactions (including *Journal of Applied Mechanics*)			$ 1,100	20,200	15,550	36,850
3a Membership List				7,000	1,500	8,500
4 ASME Mechanical Catalog				45,000	44,058	89,058
5 Publication sales (except standards, codes, and research reports)				37,680	10,236	47,916
6 Standards and codes	$ 1,000			39,250	63,232	103,482
7 Research				1,570	7,046	8,616
GENERAL SOCIETY ACTIVITIES						($220,865)
1 Society meetings (including publicity)			25,650		18,590	44,240
2 Sections (including Regional Administrative Committee of Regional Delegates Conference)		$ 16,075	43,000		15,835	74,910
3 Professional divisions			7,000		15,690	22,690
4 Student branches (including copies of MECHANICAL ENGINEERING text and advertising)		4,000	12,000	28,000	9,215	53,215
5 Admissions					20,675	20,675
6 Membership development					3,535	3,535
7 Awards			1,000		600	1,600
GENERAL SOCIETY ADMINISTRATION						($ 40,500)
1 Council		6,800	500			7,300
2 Professional services (auditors, counsel, etc.)			3,000			3,000
3 Nominating Committee		2,000				2,000
4 Retirement Fund			27,700			27,700
5 "Know Your Society" (organization charts)			500			500
JOINT ACTIVITIES						($ 20,451)
1 Engineering Societies Library	$ 11,751					11,751
2 Engineers' Council for Professional Development	1,700					1,700
3 Engineers Joint Council	1,500					1,500
4 Engineering Societies Personnel Service, Inc. (Reserve)	2,000					2,000
5 Registration (National Council State Boards of Engineering Examiners)	500					500
6 UET Pension Fund	2,500					2,500
7 National Management Council	500					500
INDIRECT EXPENSE						($172,296)
1 Secretary's office					40,845	40,845
2 Accounting department					29,260	29,260
3 General service (stores, mailing, filing, etc.)					63,970	63,970
4 General office (rent, insurance, etc.)					38,221	38,221
	$ 21,451	$ 28,875	$121,450	$299,800	$489,396	$958,022

BREAKDOWN OF ASME BUDGET—1948–1949

	Budget 1948–1949	
MECHANICAL ENGINEERING and Mechanical Catalog income	$359,000.00	
Less production costs, wages and indirect	256,957.00	$102,043.00
General publication sales income	$ 75,250.00	
Less stock cost, wages and indirect	57,537.00	17,713.00
Engineering Index		2,000.00
Miscellaneous sales		4,000.00
Interest and discount		19,000.00
Membership dues		360,000.00
TOTAL		$504,756.00
MECHANICAL ENGINEERING Text (production, wages and indirect)		$ 98,071.00
Transactions (production, wages and indirect)		44,839.00
Membership List (production, wages and indirect)		9,967.00
Standards and codes (income)	$ 96,250.00	
Stock cost, wages and indirect	123,947.00	27,697.00
Research (income)	$ 3,500.00	
Stock cost, wages and indirect	10,309.00	6,809.00
Student dues	$ 36,000.00	
Student expense (production, wages and indirect)	62,964.00	26,964.00
Meetings (income)	$ 5,000.00	
Meetings expense (costs, wages and indirect)	52,342.00	47,342.00
Sections (appropriations, travel, wages and indirect)		88,635.00
Divisions (appropriations, travel, wages and indirect)		26,846.00
Admissions and development (wages and indirect)		28,643.00
Awards (costs, wages and indirect)		1,892.00
Joint activities		37,512.00
General administration		57,561.00
TOTAL		$502,778.00
NET INCOME		$ 1,978.00

Student Branch Conferences in their Regions or arrange for visits by their representatives.

7 No travel allowance will be provided for Committee Chairmen attending Council meetings except upon special provision of Council or the Executive Committee.

8 Eight Regional Administrative Committee meetings will be held.

9 The Nominating Committee shall hold a preliminary meeting at a place to be selected and a selection meeting at a convenient place within the provisions of the budget.

10 The following uniform basis of contribution toward travel expense shall be adopted:

Five cents per mile one way plus allowance of $3.50 per diem for time at the meeting not exceeding two days plus total traveling time by standard railroad route, plus 50 per cent for the Council, Nominating Committee, Regional Administrative Committees, Sections, and Regional Delegates. When Board and Committee Chairman are required to attend Council meetings, the same provisions will be made.

For Student Branch Conference—13 cents per mile one way for one delegate from each Student Branch.

Visits of President and Vice-Presidents or their designated representatives to Sections, Branches, etc.—out of pocket expense within budgetary limits prescribed.

11 The Society shall have two representatives on the American Standards Association.

12 No publications shall be printed for sale unless there is reasonable assurance of sufficient orders to pay for the cost.

Feedwater Committee Seeks Comments on Revised Code

THE Boiler Feedwater Committee of the ASME Boiler Code Subcommittee on the Care of Power Boilers recently completed the preparation of a suggested Part B of Section VII of the ASME Boiler Code, in which rules are suggested for chemical conditioning of boiler feedwaters for boilers having higher pressures and superheat to replace the present Appendix covering feedwater analysis, treatment, and control.

The first draft of the revision, published in full on pages 557 to 560 of the June issue of MECHANICAL ENGINEERING, covers such matters as cleaning out and laying up of boilers, problems of scale, sludge, and oil, corrosion, embrittlement, forming, and carry-over and feed water testing.

In commenting on the revision, Cyrus W. Rice, chairman of the feedwater committee, said that the changes make it much easier for the operators to obtain information desired.

"The revised paragraphs on embrittlement," he continued, "avoid the confusion that results through the different published opinions covering the solution of this problem. It also avoids single suggestion of using sulphates for preventing caustic embrittlement. This is very necessary today because of the embodiment of such recommendations in State laws, with resulting hardships where sulphates have failed to prevent embrittlement, or its use has incurred other unsatisfactory operating conditions.

"The successful use of other materials and practices for treating feedwaters for preventing boiler embrittlement has had the practical experience of enough years to prove the need of this change to a broader policy. This same broad policy is embodied throughout the proposed revision in that no specific treatment is advised for the correction of any unsatisfactory conditions caused by water impurities.

"The influence of scale, corrosion, and treatments on the boiler and steam-turbine operating economies and safety of these equipments is such, especially in the high-pressure field, that it has made it necessary to employ or consult operators who are experienced or who have specialized in the work of conditioning boiler waters.

"Both the revised and existing requirements lay stress on such employments, because of the intimate and wide influence the proper conditioning of feedwaters has on both operating economies and safety of boiler and turbine operations."

In publishing the revision in full, the Subcommittee hopes to encourage constructive comments from boiler-insurance inspectors, boiler manufacturers, and steam-boiler operators, and specialists in the field of feedwater treatment.

ASME Streamlines Standards Procedure

TO facilitate operations of 23 sectional committees and seven safety committees The American Society of Mechanical Engineers has compartmented its standards work into five classifications. Each of these will become the responsibility of one member of the Standardization Committee, except for the group of safety committees, and expedited by a member of staff. This move is made in anticipation of increased activity in the standards field.

Further steps in the simplification of procedure within ASME are anticipated by the new standards manager, S. A. Tucker. Many sectional committees are in need of reorganization and some new ones are forming.

Mr. Tucker comes to ASME from McGraw-Hill Publishing Company, Inc., where he served as associate editor of *Power* for ten years, and managing editor of *Electrical World* for a brief period. This editorial experience, following active engineering with the Consolidated Edison Company of New York, will be useful to the standards work of the Society.

M.I.T. Establishes Foundry Program

TO meet the need for professionally trained men in the foundry industry, the Massachusetts Institute of Technology, Cambridge, Mass., has established a foundry program. While not intended as a four-year course, the program will include studies in metallurgy, mechanical engineering, and business administration. The program is being supported by the foundry industry which contributed laboratory equipment and provided scholarships for student research.

Reed College Campus to Be Scene of ASME 1948 Fall Meeting

REED COLLEGE on whose 100-acre campus The American Society of Mechanical Engineers will hold its 1948 Fall Meeting, Sept. 7–9, 1948, is well known for its experimental and highly individual approach to higher education. Although a young school, its work is grounded in a "distinguished liberal tradition" which has won for its graduates national reputations in the fields of education, the sciences, and public administration. The college is nondenominational, does not engage in intercollegiate athletics in the usual sense, and has no fraternities or sororities.

Five miles from Portland, Ore., the campus with its landscaped and natural beauty, is an ideal place for a technical meeting. Technical sessions will be held in Eliot Hall. Members who wish to stay on the campus will have one of the main dormitories at their disposal. For those members who may want to stay in town, the Committee is arranging hotel accommodations at the Heathman and the New Heathman Hotels. A swimming pool, tennis court, and the Eastmoreland municipal golf course adjacent to the campus, will provide opportunity for recreation.

Plans for the meeting are shaping up well. It is expected that Earl Riley, Mayor of Portland, and John H. Hall, Governor of Oregon, will participate in the welcoming ceremonies. Other speakers who are expected to address the meeting are: Walter C. Geiger, Mem. ASME, Armour Leather Company, Williamsport, Pa.; Leonard J. Fletcher, Mem. ASME, Caterpillar Tractor Company, Peoria, Ill.; Raymond Ellickson, Reed College, Portland, Ore.; Samuel H. Graf, Mem. ASME, Oregon State College, Corvallis, Ore., and Otto de Lorenzi, Fellow ASME, Combustion Engineering Company, New York, N. Y.

The following Professional Divisions are planning technical sessions: Wood Industries; Management; Power; Fuels; Hydraulic; Aviation; Materials Handling; and Metals Engineering.

Among the inspection trips being planned are visits to the Reynolds Metals Aluminum Plant, Troutdale, Ore.; one to the Mt. Hood Timberline Lodge, and some to the world's largest sawmills and plywood plants.

Engineers of the Bonneville Power Administration and the United States Corps of Army Engineers are expected to participate in the meeting by sponsoring sessions on hydroelectric developments in the Northwest.

Plans are being made for an interesting program for the wives of delegates.

Financial Aid From Industry Sought by ASA

INDUSTRY and commerce which now derive substantial benefits from services provided by the American Standards Association will soon be asked to subscribe their fair share of the $600,000 ASA budget based on actual operating costs with provision for developments. To insure continuity of the ASA program, participating organizations will be urged to pledge their support for a three-year term.

A committee of top executives who are cooperating with Howard C. Coonley, Assoc. ASME, and chairman of the ASA Executive Committee, will present the financing program to industry.

The ASME is one of the charter-member bodies of the ASA. Through its Standards department, the Society has worked closely with the association providing personnel for technical committees and creating engineering codes under the procedures set up by the Association.

THE ERIC HAUSER MEMORIAL LIBRARY, REED COLLEGE, PORTLAND, ORE., ON WHOSE CAMPUS THE ASME 1948 FALL MEETING WILL BE HELD

(Founded in 1912 at the bequest of the widow of Simeon G. Reed, pioneer Oregon industrialist and onetime steamboat king of the Columbia River, the college has achieved a reputation for its experimental and highly individual approach to higher education.)

1948 Fall Meeting Tour

MEMBERS interested in attending the ASME 1948 Fall Meeting to be held at Reed College, Portland, Ore., Sept. 7–9, 1948, should write the Secretary's office for further information about how they can enjoy an unusually fine vacation in connection with attendance at that meeting.

A personally conducted tour, with a four-day visit to Yellowstone Park and Mount Rainier National Park on the going trip, and four days in Glacier National Park on the return trip, will enable a member to obtain a large dividend on his investment for travel to the Portland meeting.

The total time will be 17 days en route from New York to New York, 15 days from Chicago to Chicago, at a cost of $450 from New York, and correspondingly lower rates from cities farther west.

350 Attend 20th National Oil and Gas Power Conference

THE Oil and Gas Power Division of The American Society of Mechanical Engineers held its 20th National Oil and Gas Power Conference at the New Jefferson Hotel, St. Louis, Mo., May 20–22, 1948. The program, which was planned to commemorate the 50th anniversary of the Diesel engine in America, attracted 350 engineers and industrialists in the oil and gas power industry. A feature of the conference was a preconference course of lectures on "Diesel Fuel Oils." In addition to six technical sessions, an exhibition of the latest Diesel equipment, and plant visits to several of the St. Louis plants added to the pleasure of the delegates.

A detailed report of the conference will be published in the August issue of MECHANICAL ENGINEERING.

Four Engineers Honored

HONORARY degrees of doctor of engineering were conferred recently on Fred Viall Larkin, Fellow ASME, director of department of mechanical engineering, Lehigh University, Bethlehem, Pa., and Ernest H. Peabody, Mem. ASME, president of Peabody Engineering Corporation, New York, N. Y., by the Stevens Institute of Technology, Hoboken, N. J.

Leigh Willard, Mem. ASME, president Interlake Iron Corporation and Interlake Chemical Company was similarly honored by the Michigan College of Mining and Technology on June 7, 1948.

James W. Parker, past-president ASME, president, Detroit Edison Company, received a similar degree from the Polytechnic Institute of Brooklyn on June 9, 1948.

ASME Calendar

of Coming Events

Sept. 7–9, 1948
ASME Fall Meeting, Reed College, Portland, Ore.

Sept. 13–17, 1948
ASME Instruments and Regulators Division Meeting, Convention Hall, Philadelphia, Pa.

Sept. 20–21, 1948
ASME Aviation Division Meeting, Hotel Dayton Biltmore, Dayton, Ohio.

Oct. 3–6, 1948
Petroleum Committee of the ASME Process Industries Division Meeting, Herring Hotel, Amarillo, Texas.

Nov. 3–4, 1948
ASME Fuels Division Meeting, Greenbrier Hotel, White Sulphur Springs, W. Va.

Nov. 28–Dec. 3, 1948
ASME Annual Meeting, Hotels Pennsylvania and New Yorker, New York, N. Y.

Jan. 10–14, 1949
Materials Handling Division and Management Division Meeting, Convention Hall, Philadelphia, Pa.

April 25–27, 1949
ASME Spring Meeting, Hotel Mohican, New London, Conn.

Industrial Power Trucks Committee Organization Meeting Held

A LARGE and enthusiastic group of manufacturers and users of industrial power trucks met in the rooms of The American Society of Mechanical Engineers on May 20, 1948, to organize a sectional committee under procedures of The American Standards Association. They will prepare a safety code to cover the manufacture and use of industrial power trucks.

Charles W. Meldram, New York district manager of the Industrial Truck Division of Clark Equipment Company, was elected chairman and C. F. Kells, representing the Electric Industrial Truck Association, was elected secretary of the committee.

Subcommittees on nomenclature, operating and traffic rules, industrial power trucks, and power-operated hand trucks were assigned to develop the code material under the following scope: Safety requirements relating to the manufacture and use of industrial power trucks, such as platform trucks, tractors, low-lift trucks, high-lift trucks, fork-lift trucks, and special industrial trucks, but not including commercial motor vehicles intended for use upon land highways; these safety requirements to include such factors as operating controls, brakes, steering, stability while lifting and carrying loads, and maneuverability.

Research on Spreader Stokers Planned

REPRESENTATIVES of eight spreader-stoker manufacturers and Bituminous Coal Research, Inc., met in Pittsburgh, Pa., recently to study means for improving the utilization of bituminous coal. This meeting was brought about by the increasing acceptance of spreader-stoker firing in industrial and public-utility plants and a desire to extend its versatility and over-all efficiency.

A Spreader Stoker Research Committee was formed to administer the program. William S. Major, Mem. ASME, development engineer of Bituminous Coal Research, Inc., was elected chairman of the committee which is composed of two representatives from the bituminous-coal industry, one from each of the co-operating spreader-stoker manufacturers, and two from Bituminous Coal Research, Inc.

Plans were formulated to conduct research tests on a representative size and type of spreader-stoker-fired boiler under the supervision of the fuel-engineering staff of Battelle Memorial Institute, Columbus, Ohio.

Section Activities

Metalworking and Management, Topics at Pittsburgh Mechanical-Engineering Conference

ADVANCES in machine-tool engineering, in hot and cold metalworking, and some of the labor-management problems which have resulted from technological advances, were topics discussed at the Pittsburgh Mechanical Engineering Conference, held at the William Penn Hotel, Pittsburgh, Pa., April 16, 1948.

The conference is sponsored annually by the Pittsburgh Section of The American Society of Mechanical Engineers in co-operation with other local engineering organizations. Among those participating in the 1948 conference were: Engineers Society of Western Pennsylvania, Society for the Advancement of Management, and American Society of Tool Engineers.

ASME Fellows Honored

At a dinner meeting which followed the technical sessions, T. E. Purcell, vice-president ASME Region V, presented Certificates of Award to Tomlinson Fort, past-chairman of the Pittsburgh Section, and W. Trinks, Fellow ASME, who served the Society as 1946-1947 lecturer. The following were honored as new Fellows of the Society: Frank Bell, W. Trinks, Thomas D. Jolly, F. C. Biggert, Jr., John Fox, and Oscar Wikander. E. W. Jacobson, chairman, ASME Pittsburgh Section, was toastmaster.

E. G. Bailey, president ASME, as the main speaker directed his remarks primarily to the younger engineers and student members, a

EXECUTIVE COMMITTEE OF THE PITTSBURGH SECTION

(*Left to right:* W. S. McKee, W. O. Lytle, W. L. Kennecott, Leo Tattersall, H. H. Hall, E. W. Jacobson, chairman, G. O. Manifold, Tomlinson Fort, A. M. G. Moody, J. Z. Linsenmeyer, Christian Wilson, Jr., and A. A. Markson.)

THREE PRESIDENTS

(*Left to right:* E. G. Bailey, president of The American Society of Mechanical Engineers; R. J. S. Pigott, president of the Society of Automotive Engineers; Thomas D. Jolly, president of The Engineers Society of Western Pennsylvania.)

large number of whom were present from the neighboring colleges. During the discussion period following the talk, President Bailey was able to give good counsel to young men who were eager to learn of the profession.

In a review of the history of the machine-tool industry, Hans Ernst, Fellow ASME, director, Cincinnati Milling Machine Company, Cincinnati, Ohio, said that with an increasing understanding of the mechanism of the metal-cutting process, the industry has been able through the years to improve accuracy, quality of finish, and speed of production. "Today we are rapidly approaching a state where the basic physical processes which underlie the production of metal chips can be expressed in mathematical terms so the art of metal cutting moves forward to the realm of science. Only in this direction can we look for the machine tool of tomorrow."

Employee Attitudes Important

Speaking on the legal aspect of technological improvements, S. H. French, manager industrial relations, Crucible Steel Company of America, Pittsburgh, Pa., said that because workers have an economic stake in maintaining the status quo of their jobs, it is fatal to ignore employee attitudes in the solution of engineering problems. Productivity and efficiency cannot be legislated, he said. "The essential of employee efficiency is the economic and enlightened self-interest of the individual worker in maintaining or increasing his output. That self-interest can operate, if at all, only in an atmosphere of voluntarism, not of compulsion."

Other subjects discussed at the conference were: New developments in balancing machines; fabrication of austenitic seamless steel sheets, and extrusion of heated metal billets.

Boston

May 27, Hotel Commander, Cambridge, Mass. Speaker: E. W. Norris, Mem. ASME, Stone & Webster Engineering Corporation, Boston, Mass. Subject: Application of Fans to Steam Boilers. Attendance: 125.

Buffalo

April 27, Mansion House, Niagara Falls, N. Y. Joint dinner meeting with Niagara County Chapter of the New York Society of Professional Engineers. Speaker: C. C. Furnas, Mem. ASME, director, Cornell Aeronautical Laboratory. Subject: Future Trends in Aviation. Attendance: 81.

Central Iowa

May 6, Ames, Iowa. Speakers: Will Robinson and Jack Baer. Subjects: Arc-Welded Vise, and Special Problem in Die Development. Attendance: 20.

May 28, Iowa State College, Ames, Iowa. Speaker: C. E. Davies, secretary ASME. Professional Development of the Young Member. Attendance: 35.

Chicago

May 12, President's night. Illinois Institute of Technology, Chicago, Ill. Speaker: E. G. Bailey, president ASME. Subject: Opportunities for Engineers. Attendance: 178.

May 18, annual party, Edgewater Beach Hotel, Chicago, Ill. Attendance: 185.

Cleveland

May 13, Cleveland Engineering Society, Cleveland, Ohio. Speaker: E. G. Bailey, president ASME. Subject: The Engineers' Opportunities. Attendance: 300.

Detroit

May, 17, Rackham Memorial Building, Detroit, Mich. Speaker: Nelson L. Davis. Subject: Material Handling—Its Need and Problems in Our Manufacturing Economy. Attendance: 300.

Louisville

April 23 and 24, Kentucky Hotel, Louisville, Ky. The Section was host to the 7th Annual ASME Conference of Region VI which consisted of 13 sections from 10 midwestern states.

North Texas

May 3, DP&L Auditorium, Dallas, Texas. Speaker: Col. J. O. Beaty, who served as chief of Interview Section, Army Intelligence, World War II. Subject: The Current World Situation. Attendance: 62.

Peninsula

May 1, Schuler Hotel, Grand Haven, Mich. Speaker: W. E. Jones, consultant, quality-control engineer, Desplaines, Ill. Subject: Principles of Quality Control. Attendance: 60.

Philadelphia

April 27, Engineers Club, Philadelphia, Pa. Speaker: Wm. L. Batt, past-president and Hon. Mem. ASME, president, SKF Industries, Philadelphia, Pa. Subject: European Needs. Attendance: 60.

San Francisco

April 22, Engineers' Club, San Francisco, Calif. Speaker: William J. Besler. Subject: Forced-Circulation Steam Generator. Attendance: 73.

May 10, Engineers' Club, San Francisco, Calif. Joint meeting with Society for The Advancement of Management. Speaker: Dean Dexter S. Kimball, past-president and Hon. Mem. ASME, dean emeritus, college of engineering, Cornell University, Ithaca, N. Y. Subject: Can Democracy Survive in a Mechanized Society? Attendance: 116.

Southern California

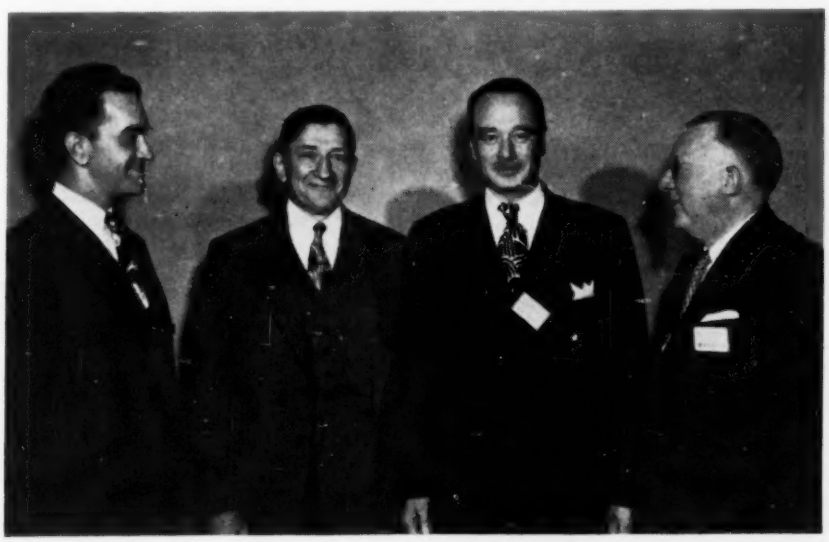
May 25, Royce Hall Auditorium, Los Angeles Campus, Westwood, Calif. Speaker: Hugh L. Dryden. Subject: Dawn of the Supersonic Age. Attendance: 900.

Southern Tier

May 13, Baker Chemical Laboratory, Cornell University. Joint meeting with Cornell University student branch. Speaker: J. Carleton Ward, Jr., Mem. ASME, chairman of the board, Fairchild Engine and Airplane Company. Subject: Harnessing the Atom—An Engineer's Viewpoint. Attendance: 115.

South Texas

April 24, Newgulf Country Club, Newgulf,



AT THE REGIONAL ADMINISTRATIVE CONFERENCE OF REGION VI

(*Left to right:* Henry V. Heuser, Ernest Hartford, T. S. McEwan, and Elmer J. Dreyer.)

OFFICERS OF WILMINGTON SUB-SECTION OF THE ASME PHILADELPHIA SECTION

(*Left to right:* A. P. Wendland, retiring secretary-treasurer; W. E. Segl, retiring chairman; C. H. Rice, new member executive committee; D. L. Arm, chairman; F. C. Evans, vice-chairman; B. A. Lininger, secretary-treasurer.)

Texas. Social meeting, followed by an inspection trip and outing to the Boling Dome plant of the Texas Gulf Sulphur Company. Attendance: 65.

May 20, Junior group, Rice Institute, Houston, Tex. Speaker: Murray Robinson of Butler, Binion, Rice, and Cook. Subject: Engineering Aspects of Patent Law. Attendance: 12.

Virginia

April 23, Euvant's Cafeteria, Richmond, Va. Speaker: F. R. Benedict, Western Electric Corporation. Subject: Engineering Materials of the Future. Attendance: 97.

Western Washington

May 12, annual spring joint meeting of the Section and the University of Washington Student Branch to honor the graduating seniors. Gowman Hotel, Seattle, Wash. Speaker: Alexander Gow; Subject: Salvage Operations of Diamond Knot. Attendance: 50

West Virginia

April 27, Charleston Woman's Club, Charleston, W. Va. Speaker: R. G. Le Tourneau, Mem. ASME, president, R. G. LeTourneau, Inc., Peoria, Ill. Subject: Moving the Earth. Attendance: 200.

Engineering Societies Personnel Service, Inc.

These items are from information furnished by the Engineering Societies Personnel Service, Inc., which is under the joint management of the national societies of Civil, Electrical, Mechanical, and Mining and Metallurgical Engineers. This Service is available to members and is operated on a co-operative nonprofit basis. In applying for positions advertised by the Service, the applicant agrees, if actually placed in a position through the Service as a result of an advertisement, to pay a placement fee in accordance with the rates as listed by the Service. These rates have been established in order to maintain an efficient nonprofit personnel service and are available upon request. This also applies to registrants whose notices are placed in these columns. Apply by letter, addressed to the key number indicated, and mail to the New York office. When making application for a position include six cents in stamps for forwarding application to the employer and for returning when necessary. A weekly bulletin of engineering positions open is available to members of the co-operating societies at a subscription of $3.50 per quarter or $12 per annum, payable in advance.

New York	Chicago	Detroit	San Francisco
8 West 40th St.	211 West Wacker Drive	109 Farnsworth Ave.	57 Post Street

MEN AVAILABLE[1]

MECHANICAL ENGINEER, BSME, recent graduate desires opportunity on machine design. Inexperienced, but offers conscientiousness, creative ability, and earnest efforts while training. East preferred. Would travel. Me-305.

JUNIOR MANUFACTURING EXECUTIVE, industrial-engineering degree, Lehigh, and graduate Harvard Business School; 5 years' production planning and control, materials handling, cost control, plus varied administrative responsibilities. Small, medium-sized company preferred. Me-306.

MECHANICAL ENGINEER, DEVELOPMENT, age 30, AB physics, BSME, 8 years' experience, emphasis on vibration problems, 2½ years supervisor of research, development, production-engineering group. Prefer Connecticut. Can travel. Me-308.

MECHANICAL ENGINEER, BSME, Sept., 1948; BA languages, married, desires engineering position requiring cultural background, initiative, resourcefulness. Three years' experience in research, development, administrative practices. Prefer permanent, challenging position, with room for advancement in medium or small concern. Me-309.

RESEARCH OR DEVELOPMENT ENGINEER, BME, 1944; 4 years' experience, both analytical and experimental on vibration, thermodynamics, and heat transfer. Single. Prefer New York metropolitan area. Me-310.

MECHANICAL ENGINEER, over 25 years' experience, design, development, research, application, and sales engineering of centrifugal, axial-flow, and propeller pumps, fans, and cooling towers. Me-311.

MECHANICAL ENGINEER, BME June, 1948; Pi Tau Sigma, 2 years' experience as draftsman, sterilizing equipment; six months' locomotive factory; seeks position as junior engineer. Location open. Me-312.

POSITIONS AVAILABLE

ENGINEERS (*a*) Mechanical engineer with degree, 25–40, with experience on refrigeration, to approve plans specifications, operating instructions, maintenance and repair for marine refrigeration. $4149; (*b*) mechanical engineer, similar duties, except for all kinds of heat-transfer equipment. $4149; (*c*) mechanical engineer specialized in industrial-gas and air-generating equipment. $5905. Washington, D. C. Y-853.

INSTRUCTORS TO ASSOCIATE PROFESSORS, 5, with master's degree in science, or better, for mechanical-engineering department. Two of the positions include the teaching of mechanical vibration and machine design, three positions include the teaching of thermodynamics and its application to power plants, turbines, and internal-combustion engines, also work in the mechanical laboratory. $3000–$5200 for nine months, depending on experience. Northern New Jersey. Y-876.

ASSISTANT OR ASSOCIATE PROFESSOR in mechanical engineering, to teach the following subjects: heat transfer, internal-combustion engines, and machine design. Positions start September, 1948. Upstate New York Y-881(b).

SALES ENGINEER, 30–45, with from 5 to 10 year's experience in industrial power-plant equipment. Should be able to make up schematic sketches on piping and assembly hookups and layouts. Should be able to handle accurately and quickly a large volume of sales correspondence. Knowledge of foreign languages helpful. Some traveling. Starting salary, $4800–$6000. Pennsylvania. Y-885.

SENIOR MECHANICAL ENGINEER, 28–35, BSME, with about 4 year's experience in developing accessories to, or redesigns of machines, to improve quality or cut processing costs, to develop new and improved processes for handling a variety of mechanical operations. De-

(*ASME News continued on page 654*)

[1] All men listed hold some form of ASME membership.

SEATLESS MEANS ECONOMY

IN BOILER BLOW-DOWN SERVICE

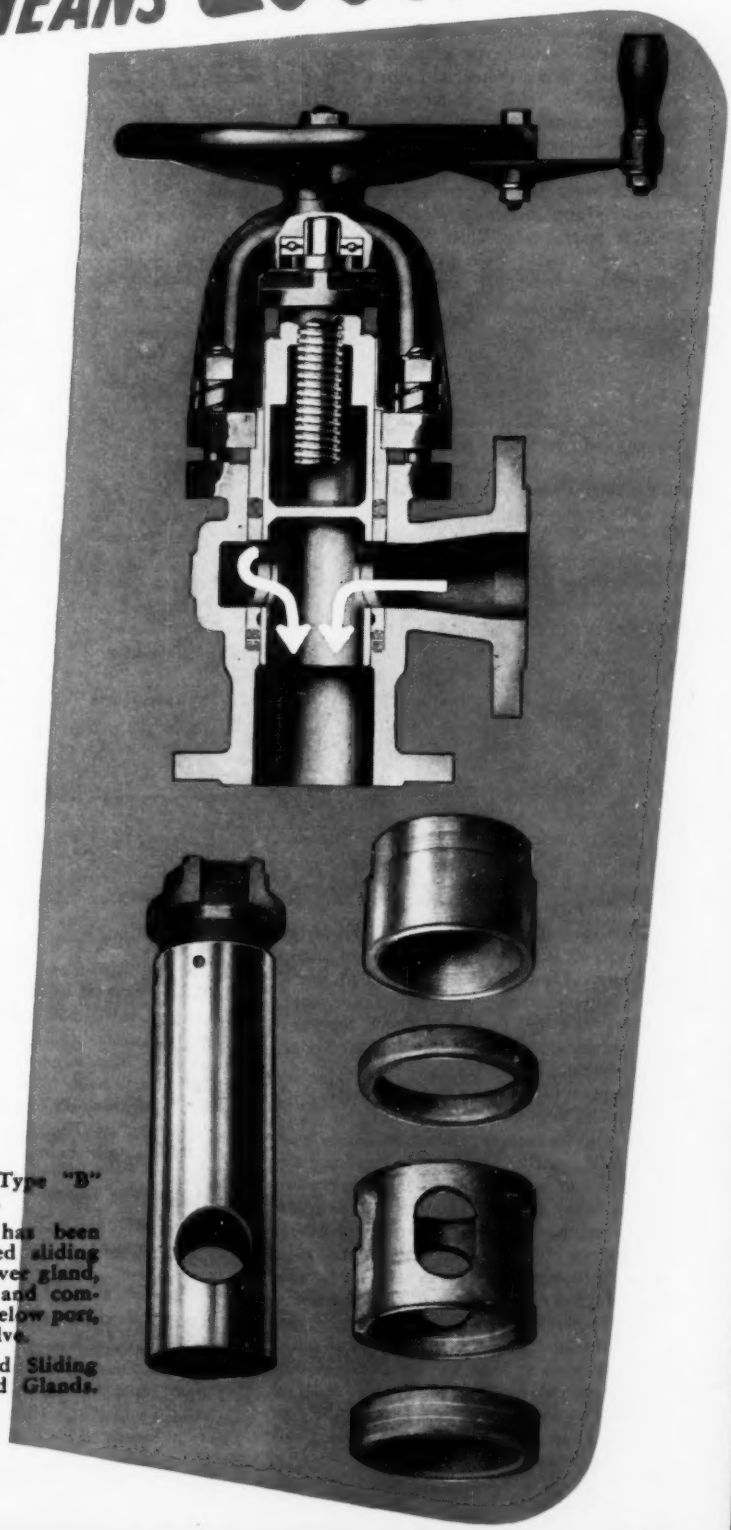
Because they eliminate the commonest source of trouble and expense in ordinary blow-off valve service, Yarway *Seatless* Blow-Off Valves mean real economy to boiler plant operators. *Yarways have no seat to score, wear, clog and leak.* Lubrication is usually the only maintenance they require.

Yarway introduced the seatless principle with the balanced sliding plunger many years ago . . . has constantly improved and adapted it to meet modern service requirements. Mechanical and metallurgical research in Yarway's own Steam Laboratory anticipates changing conditions . . . keeps Yarway valve design ahead.

There is a Yarway Blow-Off Valve for every pressure.

SEND FOR FREE BLOW-OFF VALVE BOOKLET. PLEASE INDICATE THE PRESSURE OF YOUR BOILERS.

YARNALL-WARING COMPANY
108 Mermaid Avenue, Philadelphia 18, Pa.



(*Above*)—Cross section of Type "B" Seatless Angle Valve, flanged.

OPERATION: After valve has been closed, shoulder on balanced sliding plunger contacts upper follower gland, forcing it down into body and compressing packing above and below port, making an absolutely tight valve.

(*Below*)—Type "B" Balanced Sliding Plunger, Packing Rings and Glands.

Forty Years 1908 YARWAY 1948

YARWAY BLOW-OFF VALVES

sign and develop new machines or machine accessories. $3600–$5400. Massachusetts. Y-891.

JUNIOR ENGINEER, in industrial hygiene, graduate mechanical or chemical, preferably with 1 or 2 years' experience in industrial ventilation. Some industrial-hygiene experience desirable. Will visit factories to make recommendations, design new equipment. Must be willing to spend one week per month upstate New York. Must have driver's license. Must be able to use microscope. Provisional appointment pending examination. $3450 to start. New York, N. Y. Y-897.

HEATING AND VENTILATING ENGINEER qualified to head up drafting-room group under chief mechanical engineer. Should have had some industrial experience, preferably on hospitals, schools, and housing developments. Some drafting and design on installations. About $5200. New York, N. Y. Y-898.

MECHANICAL ENGINEER with power-plant design and construction experience, to do drafting, check, and revise plans and specifications, and do general office engineering for equipment installation. $4000–$5000. New York, N. Y. Y-903.

MECHANICAL ENGINEER, 32–40, to manage manufacturing details for company assembling machinery equipment. Will also be responsible for service department. $5600–$6500. New York, N. Y. Y-906.

DESIGN-DRAFTSMAN, mechanical graduate, with minimum of 3 years' piping and equipment experience, to lay out piping and other facilities for bulk-oil plants. $4200. New York, N. Y. Y-909.

MECHANICAL-DESIGN ENGINEER experienced in stress analysis. Should also have had experience preferably in designing for the containment of detonating or explosive pressures. Work will involve substantial responsibility. Virginia. Y-924.

ENGINEERS (*a*) Chief mechanical-design engineer, 40–50, to head up division of utility company. Must have had 10 to 15 years' steam-power-station design experience. $6500–$8000. (*b*) Project engineer, mechanical, with similar background as above. $5000–$6000. Pennsylvania. Y-930.

ASSISTANT IN MARKET RESEARCH, under 40, mechanical engineer, with training through continuous business experience in sales promotion and market research. Should have experience in merchandising and sales promotion of heavy industrial equipment and appliances, or merchandise for mass markets. Familiar with usual market-research methods, and able to create new ones. Should be able to accomplish results in actually doing creative market-research work. Pennsylvania. Y-954.

INDUSTRIAL ENGINEER, 35–40, mechanical graduate, with at least 5 years' experience on wage-incentive work in a foundry or allied industry, to act in a staff capacity. Should be well versed in other phases of industrial engineering, particularly relating to production control. Will be responsible for all methods relating to time study and production control, and incentive plans. Salary open. Southern New Jersey. Y-967.

SENIOR INSTRUCTOR, mechanical graduate, with teaching and industrial experience, to supervise laboratory and classroom work in mechanical technology, covering shop training, mechanics, and materials. $4600–$5800. Westchester County, N. Y. Y-972.

CHIEF ESTIMATOR, 35–45, mechanical or chemical graduate, with at least 10 years' supervisory estimating experience covering refinery and chemical equipment, piping, instrumentation, steel and concrete structures. $8000–$10,000. Pennsylvania. Y-999.

ENGINEERS. (*a*) Recent graduates, mechanical, for 1 or 2 years' training course for manufacturing of airplane engines. $2964–$3120; (*b*) test engineer, with at least 1 or 2 years' experience testing engines, $3600–$4200; (*c*) electrical engineers, with some experience either in aircraft power plant or other industrial experience, $3600–$4200; (*d*) designers and draftsmen, mechanical, preferably with experience in aircraft engines, $3600–$5400. Northern New Jersey. Y-1004.

MECHANICAL DESIGNER, degree unnecessary, with 5 or more years in instrument design or similar work. Living accommodations furnished. Virginia. Y-1020(a).

POWERHOUSE SUPERINTENDENT, qualified to take charge of new 20,000-kw, 850-psi, 900-F public-utility generating plant. Will handle training of new personnel as well as plant operation and maintenance. At least 3 years' experience in high-pressure operation and 10 years' experience in power-plant work desirable. Salary open. Eastern New York State. Y-1022.

PLANT ENGINEER for central engineering staff of large process manufacturer. Should have knowledge of pumps, air compressors, hydraulics. Considerable traveling to various plants involved. $6000. Headquarters, New York, N. Y. Y-1035.

ASSISTANT PROFESSOR in mechanical engineering, 30–40, master's degree preferred, to teach steam engineering, thermodynamics, mechanical-engineering laboratories, and other straight mechanical-engineering courses. Industrial experience desirable. About $4000 for nine months. South. Y-1039(a).

TEACHING PERSONNEL (*a*) Instructors to teach elements of power plants and mechanical-engineering laboratory. $3000. (*b*) Instructors to teach engineering mechanics, mechanical-engineering laboratory, and other mechanical-engineering subjects. Salary, $3000–$4000, depending upon qualifications. East. Y-1041.

MECHANICAL DRAFTSMAN with building-construction experience, to detail and lay out plumbing facilities. $4160–5200. New York, N. Y. Y-1044.

INSTRUCTORS, 2, one for engineering drawing and the other for mechanical engineering. Opportunity to secure master's degree while teaching. $3300 for nine months, plus remuneration for summer teaching. R-4786-C.

CHIEF MECHANICAL ENGINEER, with extensive experience in the field of plumbing, heating, air conditioning, utility and process pipe construction to take charge of engineering department comprising estimating, material control and scheduling, drafting, take-off, and requisitions. Apply by letter with full details, salary expected, and when available. Northwest. S-687.

Candidates for Membership and Transfer in the ASME

THE application of each of the candidates listed below is to be voted on after July 26, 1948, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member who has either comments or objections should write to the secretary of The American Society of Mechanical Engineers immediately.

KEY TO ABBREVIATIONS

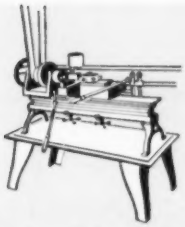
Re=Re-election; Rt=Reinstatement; Rt. & T=Reinstatement and Transfer to Member.

NEW APPLICATIONS

For Members, Associate, or Junior

ANCKER, CLINTON JAMES, JR., Berkeley, Calif.
ARCHIBALD, FRANK R., Princeton, N. J.
ATWOOD, KINGSTON ELMER, Boston, Mass.
BAIRD, JOHN MULLAN, Hammond, Ind.
BEATTIE, KENNETH WM., York, Pa.
BECK, GEBHARD C., Hollis, N. Y. (Rt)
BEGG, JOHN, Sumter, S. C. (Rt)
BERG, SVERRE, Erie, Pa.
BLATTNER, WILLIAM OWEN, Milwaukee, Wis. (Rt & T)
BOYER, JOHN RUDOLPH, Avondale, Pa. (Rt & T)
BRANDT, CARL RAYMOND, Kodiak, Alaska
BRENTLINGER, JOHN MOORE, JR., Wilmington, Del.
BUCHANAN, RAYMOND M., Wexford, Pa.
BUCHBINDER, HAROLD GABRIEL, Grove Hall, Mass.
BUSH, REGINALD I., Library, Pa.
CAMERON, HUGH C., Omaha, Neb.
CAPLE, DAVID JOHN, Malton, Ont., Can.
CARLSON, GUNARD O., Thorndale, Pa.
CAUGHEY, CARL W., Grand Rapids, Mich.
COCHRAN, JOHN WALLACE, Alliance, Ohio
COOPER, RICHARD FRANCIS, Rochester, N. Y. (Rt & T)
CUMMINGS, ROGER B., Waukesha, Wis.
DAWSON, FRANCIS M., Iowa City, Iowa
DELEON, PAUL ANTHONY, JR., Milwaukee, Wis.
DE NADOR, EMORY, Montclair, N. J.
DE NEUFVILLE, ALBERT, Mendham, N. J.
DICK, GEORGE M., Sherbrooke, Que., Can.
DOLIO, JOHN, Chicago, Ill.
DRAYTON JOHN WELSH, JR., Newton Square, Pa.
DUNTON, JOHN T., Sharon Hill, Pa.
EDWARDS, LEO M., Stepney Depot, Conn.
EDWARDS, M. LOWELL, Longview, Wash.
ELDER, FRANCIS EDGAR, Oak Ridge, Tenn.
EPPENBACH, EDWIN G., Manhasset, L. I., N. Y.
ERISMAN, MAURICE J., Los Angeles, Calif.

(*ASME News continued on page 656*)



The first successful turret lathe and the first Roots Blower were built in the same year . . . 1854. We're not good because we're old, but old because we're good.

THE FIRST POUND OF IRON WAS MADE WITH AIR

(Photograph by courtesy of Inland Steel Company, from their motion picture "The Drama of Steel".)

Battery of five big R-C Centrifugal Multi-stage Boosters and Exhausters in a midwestern steel plant.

According to recollection of oldest employees at foundry where this R-C Rotary Positive Blower is installed, it's been giving dependable service for more than 38 years.

For the earliest melting of iron ore, air was supplied by crude, man-power bellows. Today, with a ton of pig iron requiring 2,500 pounds of air, high-capacity, power-driven blowers do the work.

This requires the greatest care in selecting blowers matched to the job. One reason for the frequent specification of Roots-Connersville equipment is our 94-year record for reliable performance.

Another important factor is R-C *dual-ability* to supply either Rotary Positive or Centrifugal units. We are unbiased in our recommendations of whichever type best meets the service demands. Roots-Connersville is the only blower builder giving you this *dual choice*.

For large capacities or for small, built-in applications, as low as 5 CFM, consult R-C *dual-ability* for your blower needs.

ROOTS-CONNERSVILLE BLOWER CORPORATION
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BLOWER BUILDERS R-C SINCE 1854
BLOWERS · EXHAUSTERS · BOOSTERS · LIQUID AND VACUUM PUMPS · METERS · INERT GAS GENERATORS

★ ★ ONE OF THE DRESSER INDUSTRIES ★ ★

FISHEL, GEORGE A., Jeannette, Pa.
FRINK, LOREN HENRY, Kansas City, Mo.
GIESL-GIESLINGEN, ADOLPH, Washington, D.C.
GREENE, ROBERT E., Lancaster, Ohio
HANSCOM, HARRIS F., Providence, R. I.
HANSFORD, VANBUREN NELSON, Pittsford, N. Y.
HERRMANN, FRANK W., Glendale, L. I., N. Y.
HIRSCHHORN, HARRY G., Richmond, Va.
HOLLINGSWORTH, DWIGHT F., Avondale, Pa.
JAMES, WINFIELD HENRY, New York, N. Y.
JOHNSON, RICHARD A., Chicago, Ill.
KAISER, WILLIAM H., Wilmington, Del.
KEMPF, RUPERT E., Sausalito, Calif.
KENNEDY, JOHN M., Glendale, Calif.
KEREKES, EMERY B., Greensburg, Pa.
KINSEL, HAROLD W., Boston, Mass.
KITTREDGE, WILLIAM R., Savannah, Ga.
LEE, JOHN F., Dorchester, Mass.
LENGBRIDGE, JOHN W., Toronto, Ont., Can.
LOISEL, HENRY J., New Orleans, La.
LORING, ALBERT D., Cincinnati, Ohio
MAPEL, ROBERT W., Los Angeles, Calif.
MARTIN, CARLYLE B., Moundsville, W. Va.
MARTIN, GERALD N., Montreal, Que., Can.
MCCAULEY, KENNETH G., Clintonville, Wis.
MCINTYRE, SIDNEY S., JR., Sedro-Woolley, Wash.
MC FEELEY, ROBERT A. J., Greensburg, Pa.
MCLAY, STANLEY, New York, N. Y.
MEGNA, VINCENT ANTHONY, New York, N. Y.
MESENBURG, JOHN L., Stockton, Calif. (Rt)
MEYER, WALTER A., Milwaukee, Wis. (Rt)
MITCHELL, EDWARD J., JR., Lompoc, Calif.
MOHL, HAROLD H., Davenport, Iowa
MONSON, CHESTER A., Chicago, Ill.
MOORE, HORACE GREELEY, Wilmington, N. C.
MORSE, RICHARD K., Muskegon, Mich. (Rt & T)
MOSES, ALEXANDER K., JR., Elyria, Ohio
NICKERSON, KARL, Cincinnati, Ohio
OSTER, CLETUS J., Los Angeles, Calif.
OWEN, MARK B., Indianapolis, Ind.
PETERS, HANS A., Great Neck, L. I., N. Y.
PORTER, JOHN C., Rock Hill, S. C. (Rt & T)
RANNA, JOSEPH J., New Orleans, La.
REDOVICH, ROBERT P., Milwaukee, Wis.
RICHARDS, THOMAS B., Selinsgrove, Pa.
RIESENBERG, WILLIAM P., Pinole, Calif.
ROESCH, ERNEST, Lodi, Calif.
ROSSI, JOHN AUGUST, San Francisco, Calif.
ROTH, GEORGE L., Lorain, Ohio
RUTEU, WILLIAM HENRY, Baldwin, N. Y.
SALTER, LUDWIG L., Trenton, N. J.
SAPEGA, AUGUST EDWARD, Scranton, Pa.
SEXTON, JOHN JOSEPH, Mankato, Minn.
SILBERSTEIN, HANS, Loughborough, Leicester, England
SHAW, EDWIN C., Chicago, Ill.
SHIELDS, RICHARD W., Fulton, N. Y.
SPAINHOWER, JOHN V., Knoxville, Tenn.
STAPLETON, FREDRIC S., Binghamton, N. Y.
STILWELL, VICTOR E., North Plainfield, N. J.
STOSKOPF, ELDEN G., Chicago, Ill.
STOVER, ROLLAND S., Marshalltown, Iowa.
THOMSON, HUGH M., Salt Lake City, Utah (Rt & T)
VANDERVORT, RICHARD K., Johnson City, N. Y.
VON SCHUTZ, WERNER E. F., Stuttgart, Germany (Rt)
WARD, DONALD A., Scottsville, N. Y.
WATSON, ALVIN D., Seaford, Del.
WELCH, WILLIAM H., Jeannette, Pa.
WILKINSON, CYRIL J., Aurora, Ill.
WILSON, CLYDE A., Long Beach, Calif.
WOLFORD, EDWIN B., Los Angeles, Calif.
ZUCKERMAN, HENRY, Bronx, N. Y.

CHANGE IN GRADING

Transfer to Fellow

BULLARD, EDWARD P., Bridgeport, Conn.

Transfers to Member

BERNER, GERARD H., Baltimore, Md.
BOGDANOFF, JOHN L., Pearl River, N. Y.
DARLING, KENNETH MASON, Hamden, Conn.
FAYERWEATHER, F. OAKLEY, JR., Allendale, N. J.
FOWLER, FRANCIS R., Ballston Lake, N. Y.
GOLWELKAR, WASUDEO G., Bombay, India
GRAY, ALEXANDER J., Cincinnati, Ohio
JONES, RALPH W., JR., Chicago, Ill.
JUDSON, CHARLES J., Eugene, Ore.
KEYAK, KARL S., San Francisco, Calif.
LAWSON, EDWARD C., JR., Newark, Del.
LEBEAU, GEORGE B., PAWTUCKET, R. I.
LOOMIS, WAYLAND E., W. Hartford, Conn.
MAXWELL, RICHARD B., Brooklyn, N. Y.
MULLER, RICHARD J., Easton, Pa.
NORDLIE, FREDERICK R., Beloit, Wis.
PATTERSON, ROBERT O., Chicago, Ill.
SCHLITZKUS, ROBERT F., Oakland, Calif.
ZAREH, EDWARD, Los Angeles, Calif.

Transfer to Associate

HAMLIN, PERLEY C., Los Angeles, Calif.

Transfers from Student Member to Junior 448

Sloan Fellowships at M.I.T. Re-Established

A GRANT of $225,000 to the Massachusetts Institute of Technology, Cambridge, Mass., for a three-year program of research in the field of executive development and an educational program for a group of outstanding young business executives, was announced recently by the Alfred P. Sloan Foundation, New York, N. Y.

The grant provides for the re-establishment of the Sloan-sponsored fellowship program, which was carried on for a number of years prior to 1942 and was discontinued during the war. The new project, which will be a cooperative activity of the department of business and engineering administration and economics and social science of Massachusetts Institute of Technology, will be started again in the autumn of 1949. Prof. Gerald B. Tallman has been appointed director of the program.

Fellowships will be awarded to young business executives who show outstanding promise for leadership in their own companies and for service to our industrial society. They will come to the Massachusetts Institute of Technology on leave of absence from their employing companies for a year of graduate work in the fields of business administration and economics, and will have an opportunity to become familiar with the fundamental problems with which business management deals. Through a series of seminars and field trips, the Sloan fellows will be brought into touch with many of the best minds in business management, in government, and in labor for intensive discussions of these problems.

Necrology

THE deaths of the following members have recently been reported to headquarters:

BENET, LAURENCE V., May 21, 1948
BUCKWALTER, TRACY V., March 4, 1948
DAVIS, RICHARD F., May 20, 1948
DAYTON, FRANK, April 7, 1948
DIERCKX, JULES, May 21, 1948
FEICHT, EDWARD R., March 22, 1948
KELLY, JOHN P., May 16, 1948
OSTERMANN, RUDOLF M., May 3, 1948
REBER, LOUIS E., May 12, 1948
SIMONS, RADCLIFFE M., date not known
SMITH, ALLEN C., date not known
SULLIVAN, CLAYTON L., date not known
WEST, FRANK R., November 11, 1947
WHITE, RAYMOND E., November, 1947

ASME Transactions for June, 1948

THE June, 1948, issue of the Transactions of the ASME, which is the *Journal of Applied Mechanics*, contains:

TECHNICAL PAPERS

A Tabular Method of Calculating Helicopter Blade Deflections and Moments, by N. O. Myklestad

Tensorial Analysis of Control Systems, by Gabriel Kron (Paper No. 47—A-152)

Impact of a Mass on a Damped Elastically Supported Beam, by W. H. Hoppmann, 2nd (Paper No. 47—A-144)

The Hydrosphere—A New Hydrodynamic Bearing, by M. C. Shaw and C. D. Strang, Jr. (Paper No. 47—A-122)

A Mechanical Analyzer for the Solution of Vibration Problems of a Single Degree of Freedom, by E. E. Weibel, N. M. Cokyucel, and R. E. Blau (Paper No. 47—A-52)

Aerodynamic Oscillations in Suspension Bridges, by Edmund Pinney

Reinforcement of a Small Circular Hole in a Plane Sheet Under Tension, by Samuel Levy, A. E. McPherson, and F. C. Smith

DESIGN DATA

Tables for Numerical Solution of Problems in Compressible Gas Flow With Energy Effects, by A. H. Shapiro and G. M. Edelman

DISCUSSION

On previously published papers by Chih-Bing Ling; George Sachs; C. W. MacGregor and L. F. Coffin, Jr.; E. G. Odley; A. H. Shapiro and W. R. Hawthorne; H. Poritsky, C. W. Hewlett, Jr., and R. E. Coleman, Jr.; Alice Winzer and W. Prager

BOOK REVIEWS